

HP 3235 Switch/Test Unit

HP 34521 AC/DC Source Module

Programming and Configuration Manual

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
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Introduction

This manual is divided into six sections:

- **Module Description** contains an overall description of the module.
- **Output Connectors and Functions** describes the module's BNC connectors and discusses the types of signals the module can generate.
- **Configuring the HP 34521** describes how to configure the module for generating voltage and current outputs and discusses the programming commands involved.
- **Using the HP 34521** describes how to program the module to generate voltage and current outputs, shows how to trigger the module, and discusses three AC triggering modes.
- **Command Summary** summarizes the commands referenced in this manual.
- **Specifications** lists the specifications for the module.

NOTE

The examples used in this manual are intended for Hewlett-Packard Series 80, Series 200, or Series 300 computers using HP BASIC language. They assume an HP-IB interface select code of 7 and a device address of 09 (factory address setting) resulting in a combined HP-IB address of 709. We recommend you retain this address to simplify programming.*

The commands used to program the HP 34521 AC/DC Source Module require HP 3235 firmware revision 2750 or greater.

*HP-IB (Hewlett-Packard Interface Bus) is Hewlett-Packard's implementation of IEEE Standard 488-1978 and ANSI MC1.1.

Module Description

The HP 34521 AC/DC Source Module has the precision and versatility to generate AC waveforms as well as accurate DC voltages and currents. Standard AC sine, ramp, and square waveforms can be generated with variable amplitude and DC offset. Sine and square waveforms can be generated with output frequencies up to 1 MHz. Ramp waveforms can be generated with output frequencies up to 100 kHz. For added flexibility, you can create your own user-defined arbitrary waveforms with variable amplitude, DC offset, and frequency of repetition up to 1 MHz. The module provides an output impedance of 0Ω or 50Ω for all AC and DC voltage outputs.

Signals generated by the module are accessible from a BNC connector on the terminal block or from any one of the HP 3235's four analog buses. For all AC and DC outputs, the autorange function can be used to automatically select the voltage or current range which will provide the highest resolution. You may also select a specific output voltage or current range. Remote-sensing is available for generating DC voltages and AC sinewave voltages used in conjunction with the HP 34520 Multimeter Module.

The module generates AC waveforms (sine, ramp, square, and arbitrary) using direct digital synthesis which provides high frequency accuracy and resolution to 1 millihertz. Several AC triggering modes are available for added flexibility. The module generates DC voltages and currents using a high- or low-resolution mode which you select. The greatest amount of accuracy is available in the high-resolution mode which provides six digits of resolution. The low-resolution mode provides faster settling time and three digits of resolution.



WARNING

***SHOCK HAZARD.** When GUARD is isolated from earth ground (floating) in an HP 3235 with a module containing BNC connectors (HP 34504, 34505, 34506, 34508, or 34521), you must limit all external inputs to less than 42V peak (referenced to earth ground). If you exceed this limit and a fault occurs, hazardous voltages could be applied to exposed metal on the BNC connectors and cables. This condition could cause injury if anyone touches the exposed metal on the connectors or cables.*

When the cardcage is isolated, GUARD floats from chassis ground. Otherwise, GUARD and chassis are at the same potential. Refer to Chapter 2 of the HP 3235 Programming and System Information Manual for more information on isolating GUARD from chassis ground.

CAUTION

The HP 34521's maximum terminal voltages are:

Signal Output Connector to GUARD or Chassis: $\pm 42\text{V DC+AC Peak}$
GUARD to Chassis: $\pm 42\text{V DC+AC Peak}$

If these limits are exceeded, the HP 34521 and possibly the mainframe and extenders will be damaged. The HP 34521's output circuitry is specified to source up to 100 mA and is current-limited at approximately 120 mA. Application of voltages higher than $\pm 15\text{ V}_{\text{peak}}$ external to the output terminal may open the output relays. (The module contains five output relays: one for the output BNC connector and one for each of the four analog buses.) The backplane relays are fused for additional protection.

Output Connectors and Functions

This section discusses the module's BNC connectors, the output functions (DC voltage, DC current, and AC voltage), and shows the ranges and resolutions available for each output function.

BNC Connectors

Figure 1 shows the module's female BNC connectors and the label supplied with the terminal block. The module's BNC connectors accept standard male BNC connectors (user-supplied) or the BNC connectors supplied with the cable or bulkhead terminal blocks. The cable terminal block is supplied with the HP 34521A and the bulkhead terminal block is supplied with the HP 34521B. The BNC connectors allow you to route voltage or current outputs to the terminal block (OUTPUT connector), access a SYNC signal for AC waveforms (SYNC OUT connector), accept or provide an external reference frequency (FREQ REF connector), and accept or provide an external trigger signal (TRIGGER connector).

The three BNC connectors are TTL-compatible. The FREQ REF and TRIGGER connectors can be programmed as inputs or outputs. Inputs on the TRIGGER connector are usable to 1.1 MHz with a minimum pulse width of 250 nS. The input lock range for FREQ REF is 1073741.824 Hz ± 100 ppm. The output lock range for FREQ REF is 1073741.824 Hz ± 50 ppm.

WARNING

SHOCK HAZARD. In case of an HP 34521 component failure, voltages on the backplane analog buses may be connected to the module's front connectors and BNC connector shields. Regard all connectors as being at the same voltage as the highest voltage applied to any connector. Only qualified, service-trained personnel who are aware of the hazards involved should install, remove, or configure any module. Before touching any installed module, turn off all power to the mainframe, extenders, and external devices connected to the mainframe, extenders, or modules.



AC/DC Source Module

CAUTION

TO PREVENT CONNECTOR BREAKAGE, do not attempt to remove a terminal block from a plug-in module without using the extractors or quick interconnect mechanism (when terminal blocks are installed in a quick interconnect fixture). Install plug-in modules into the card cage before installing terminal blocks. Secure the module in the card cage with mounting screws at the top and bottom of the plug-in module connector.

Modules secured in the card cage provide connector support when terminal blocks are installed and removed. When removing a terminal block not in a quick interconnect fixture, ALWAYS use extractors to partially disengage the terminal block from the module. Failure to do this can excessively stress the connector when one side of the terminal block is disengaged and the other side is still fully engaged. Attempting to pull the terminal block off creates a lever arm which pivots on the engaged connector end, thus breaking the connector.

CAUTION

To prevent damage to the module, use clean-handling and anti-static techniques when handling the module. Do not install a module without its metal covers attached.

DC Voltage Outputs

The module generates DC voltages on one of two ranges in the high-resolution mode or on one of seven ranges in the low-resolution mode (refer to "Selecting the DC Resolution Mode" for more information). In addition to the resolution mode selected, the output ranges are dependent upon the output impedance mode which you select (refer to "Setting the Output Impedance" for more information). Table 1 shows the two high-resolution DC voltage ranges and maximum programmed output values available in the 0Ω and 50Ω output impedance modes. Table 2 shows the seven low-resolution DC voltage ranges and maximum programmed output values available.

The values shown in Tables 1 and 2 assume that the module is terminated with a 50Ω load when in the 50Ω mode. If this is not the case in your application, the actual voltage output from the module will depend on the value of your load. For example, if you have selected the 50Ω mode but have terminated the module with an open circuit, the actual output voltage will be twice the programmed voltage.

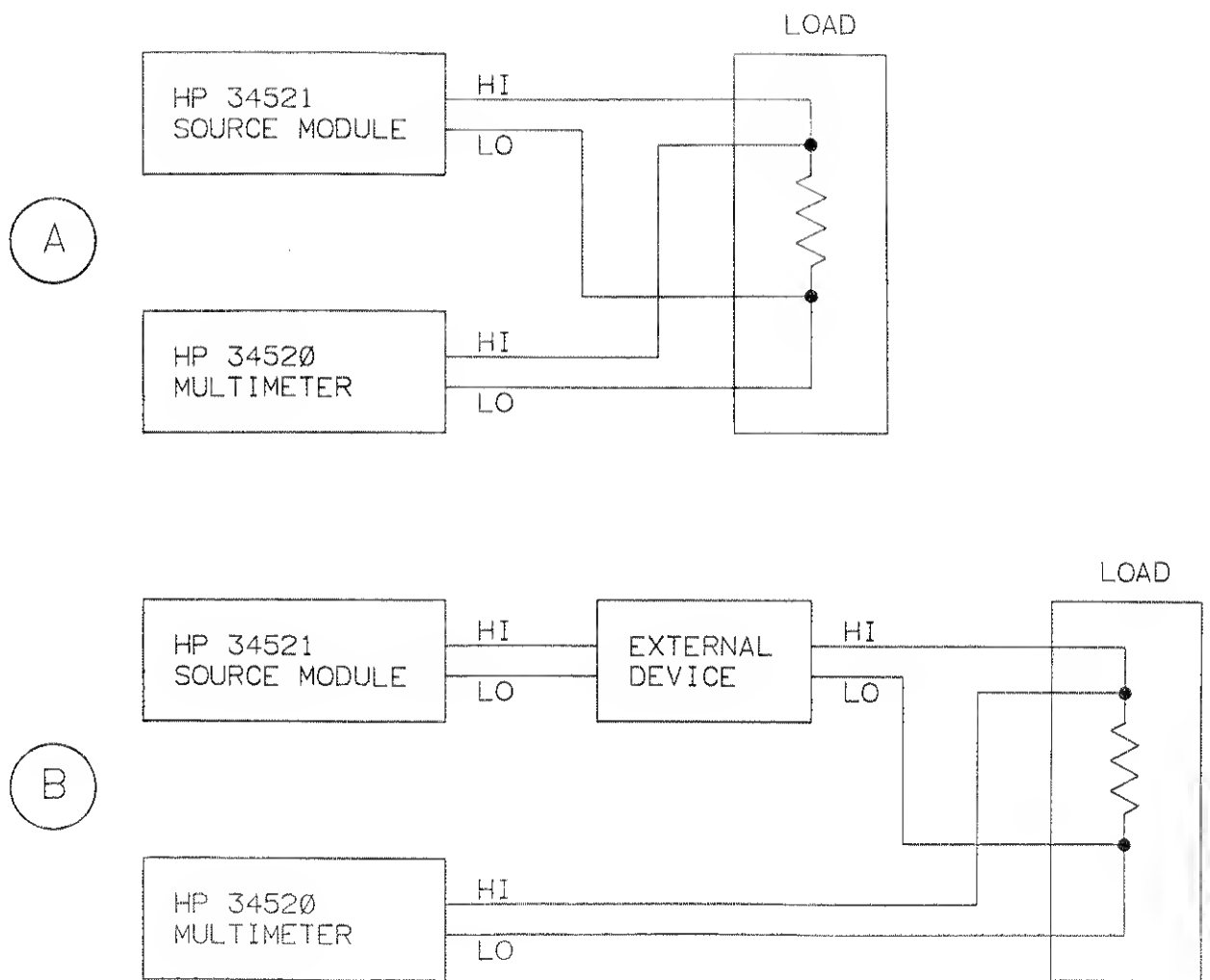
Table 1. DC Voltage Ranges (High-Resolution Mode)

Output Impedance	Range	Maximum Programmed Output	Resolution
0 Ω	1V	1.25V	1 μ V
0 Ω	10V	10.25V	10 μ V
50 Ω	0.5V	0.625V	0.5 μ V
50 Ω	5V	5.125V	5 μ V

Table 2. DC Voltage Ranges (Low-Resolution Mode)

Output Impedance	Range	Maximum Programmed Output	Resolution
0 Ω	0.15625V	0.15625V	78 μ V
0 Ω	0.3125V	0.3125V	156 μ V
0 Ω	0.625V	0.625V	312 μ V
0 Ω	1.25V	1.25V	625 μ V
0 Ω	2.5V	2.5V	1.25 mV
0 Ω	5V	5V	2.5 mV
0 Ω	10V	10V	5 mV
50 Ω	0.078125V	0.078125V	39 μ V
50 Ω	0.15625V	0.15625V	78 μ V
50 Ω	0.3125V	0.3125V	156 μ V
50 Ω	0.625V	0.625V	312 μ V
50 Ω	1.25V	1.25V	625 μ V
50 Ω	2.5V	2.5V	1.25 mV
50 Ω	5V	5V	2.5 mV

Remote-sensing is available for DC voltage outputs used in conjunction with the HP 34520 Multimeter to ensure that an accurate DC voltage is present at the load. The HP 34521 generates remote-sensed DC voltages using the ranges shown in Tables 1 and 2. Figure 2 shows block diagrams of the HP 34520 Multimeter and HP 34521 Source Module in two remote-sensing configurations. In the first configuration (block diagram "A"), remote-sensing is used to compensate for voltage losses in the test leads between the HP 34521 and the load. In the second configuration (block diagram "B"), remote-sensing is used with the HP 34521 to control an external device such as a voltage-programmed power supply.



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Figure 2. Remote-Sensing Block Diagrams

DC Current Outputs

The module generates DC currents on one of four ranges in the high- or low-resolution mode (refer to "Selecting the DC Resolution Mode" for more information). Table 3 shows the four DC current ranges and maximum programmed output values available.

Table 3. DC Current Ranges

Range	Maximum Programmed Output	RESOLUTION	
		High-Resolution	Low-Resolution
0.0001A	0.0001A	0.1 nA	50 nA
0.001A	0.001A	1 nA	500 nA
0.01A	0.01A	10 nA	5 μ A
0.1A	0.1A	100 nA	50 μ A

Before making connections to the module's OUTPUT connector for DC current outputs, you should consider the module's *compliance voltage*. To ensure accurate current outputs, the total voltage drop from the center conductor of the OUTPUT connector to shield should not exceed the compliance voltage. On the 0.1A range, the compliance voltage is 8 volts. On all other DC current ranges, the compliance voltage is 10 volts. Since the compliance voltage equals the total circuit resistance multiplied by the output current, the maximum load resistance for a 0.1A output from the module is 80 Ω .

AC Voltage Outputs

The module generates sine, ramp, square, or arbitrary waveforms on one of seven ranges in the 0 Ω or 50 Ω output impedance mode. Table 4 shows the AC voltage ranges and maximum programmed output values available in each output impedance mode. You can set the output amplitude from 10% to 100% of the specified range. Therefore, in the 0 Ω mode, the module can generate waveforms with peak-to-peak amplitudes between 0.03125 VPP and 20 VPP. In the 50 Ω mode, the module can generate waveforms with peak-to-peak amplitudes between 0.015625 VPP and 10 VPP.

When the autorange function is disabled, an error is generated if you attempt to set the peak-to-peak amplitude less than 10% or greater than 100% of the present range. When autorange is enabled, an error is generated if you attempt to set the peak-to-peak amplitude less than 10% of the lowest available voltage range or greater than 100% of the highest available voltage range. (Refer to "The Autorange Function" for more information on using autorange.)

The values shown in Table 4 assume that the module is terminated with a 50 Ω load when in the 50 Ω mode. If this is not the case in your application, the actual voltage output from the module will depend on the value of your load. For example, if you have selected the 50 Ω mode but have terminated the module with an open circuit, the actual output voltage will be twice the programmed voltage.

Table 4. AC Voltage Ranges

Output Impedance	Range (Volts P-P)	Maximum Programmed Output (Volts P-P)	Resolution
0 Ω	0.3125V	0.3125V	156 μ V
0 Ω	0.625V	0.625V	312 μ V
0 Ω	1.25V	1.25V	625 μ V
0 Ω	2.5V	2.5V	1.25 mV
0 Ω	5V	5V	2.5 mV
0 Ω	10V	10V	5 mV
0 Ω	20V	20V	10 mV
50 Ω	0.15625V	0.15625V	78 μ V
50 Ω	0.3125V	0.3125V	156 μ V
50 Ω	0.625V	0.625V	312 μ V
50 Ω	1.25V	1.25V	625 μ V
50 Ω	2.5V	2.5V	1.25 mV
50 Ω	5V	5V	2.5 mV
50 Ω	10V	10V	5 mV

Remote-sensing is available for AC sinewave voltages used in conjunction with the HP 34520 Multimeter to ensure that an accurate sinewave voltage is present at the load. (Remote-sensing is not available for ramp, square, or arbitrary waveforms.) The module generates remote-sensed sinewave voltages using the ranges shown in Table 4. Figure 2 (earlier in this section) shows block diagrams of the HP 34520 Multimeter and HP 34521 Source Module in two remote-sensing configurations. In the first configuration (block diagram "A"), remote-sensing is used to compensate for voltage losses in the test leads between the HP 34521 and the load. In the second configuration (block diagram "B"), remote-sensing is used with the HP 34521 to control an external device.

Configuring the HP 34521

This section shows how to prepare the module for generating voltage and current outputs. This includes selecting the module's output terminal, output impedance mode, output voltage or current range, and output delay time.

Power-On State

When you apply power to the mainframe or extender, the HP 34521 sets itself to predefined power-on values. This is called the module's *power-on state*. Table 5 shows the HP 34521's power-on state.

Table 5. HP 34521 Power-On State

Item	Related HP 34521 Command	Power-On State
Output Function	APPLY	DC Volts (0.00 VDC)
Autorange Mode	ARANGE	On
DC Offset	DCOFF	0 Volts
DC Resolution Mode	OCRES	High-Resolution Mode
Delay Time	OELAY	0.04 Seconds
Duty Cycle	OUTY	50%
Frequency	FREQ	1000 Hz
Output Impedance Mode	IMP	0 Ohms
Phase Angle	PANG	0 Degrees
Range	RANGE	1V (Autorange)
Reference Frequency Input	REFIN	Internal
Reference Frequency Output	REFOUT	Off
AC SYNC Destination	SYNCOUT	Off
Output Terminal	TERM	Front
Input Trigger Source	TRIGIN	High
Triggering Mode	TRIGMODE	Off
Output Trigger Mode	TRIGOUT	Off

Each item in Table 5 is discussed later in this manual. The HP 3235 Language Reference Manual also lists the power-on and default values for each command. (A default value is the value selected when you execute a command but do not specify a value for an optional parameter.)

Reset State

The reset function returns the module to its power-on state without cycling power. The reset function aborts any outputs in progress and purges all voltage and current values from the module's internal storage buffer. To reset the module in mainframe slot 200 for example, send:

```
OUTPUT 709; "RESET 200"
or
OUTPUT 709; "RST 200"
```


Selecting the Source Module

Commands that are specifically for the HP 34521 do not specify an address in their command statements. Therefore, before sending any commands to the HP 34521, send the **USE** command to designate which module (i.e., which slot) will receive subsequent commands. Once you send the **USE** command, it is remembered and it is not necessary to send **USE** prior to subsequent commands sent to the module in that slot.

Specifying a USE Slot

You can change the **USE** slot by sending another **USE** command. After designating the **USE** slot, subsequent source module commands are sent to that slot. For example, to designate the HP 34521 in mainframe slot 200, send:

```
OUTPUT 709; "USE 200"
```

Unless otherwise stated, the remaining examples in this manual assume that the HP 34521 is installed in the designated **USE** slot.

Checking the USE Slot

The **USE?** query command returns the slot number (in the form *es00*) of the designated **USE** slot. The following program reads and displays the **USE** slot.

```
10 OUTPUT 709; "USE?"
20 ENTER 709; A
30 PRINT "USE Slot is "; A
40 END
```

Selecting the Output Terminal

The **TERM** command enables you to route voltage or current outputs to either the module's front **OUTPUT** connector or to one of the HP 3235's internal analog buses (AB0, AB1, AB2, or AB3). At power-on, the front connector is selected. To change the output terminal from the front connector to analog bus 1 for example, send:

```
OUTPUT 709; "TERM AB1"
```

Or, you can disconnect all outputs from the module by sending:

```
OUTPUT 709; "TERM OPEN"
```

To return to the front connector, send:

```
OUTPUT 709; "TERM FRONT"
```

NOTE

EXCESSIVE TERMINAL VOLTAGE ERROR. If an external signal is applied to the selected output terminal and is large enough to damage the module (greater than $\pm 15 V_{peak}$), the HP 34521 automatically opens the appropriate output relay to protect itself. If one of the output relays opens, the "EXCESSIVE TERMINAL VOLTAGE" error is generated. In order to continue operation, the external signal must be removed and the module must be reset.

Setting the Output Impedance

The **TERM?** query command returns a string ("FRONT", "OPEN", "AB0", etc.) indicating which output terminal has been selected for use on the module in the **USE** slot. The following program reads and displays the selected output terminal.

```
10 OUTPUT 709; "TERM?"
20 ENTER 709; A$
30 PRINT A$
40 END
```

For DC voltage outputs and AC voltage outputs (sine, ramp, square, and arbitrary waveforms), you can set the output impedance to 0Ω or 50Ω using the **IMP** command. At power-on, the output impedance is set to 0Ω . To change the output impedance to 50Ω , send:

```
OUTPUT 709; "IMP 50"
```

To return to the 0Ω mode, send:

```
OUTPUT 709; "IMP 0"
```

In the power-on 0Ω mode (**IMP 0**), the voltage output from the module will equal the programmed output voltage with or without load termination. For example, if you program the module to output 2 VDC in the 0Ω mode, the actual output voltage will be 2 VDC with or without load termination. However, in the 50Ω mode (**IMP 50**), the actual output voltage will equal the programmed output voltage **ONLY** when the module is terminated with a 50Ω load. For example, if you program the module to output 2 VDC in the 50Ω mode, the actual output voltage will be 2 VDC only when the module is terminated with a 50Ω load. If the load is removed and replaced with an open circuit, the output voltage will double to 4 VDC.

When you change the output impedance from 0Ω to 50Ω , or vice versa, the module automatically enables the autorange function. Refer to "The Autorange Function" for more information on using autorange.

If the present DC or AC output voltage is generated in the 0Ω mode and is greater than the maximum programmed output in the 50Ω mode (see Tables 1, 2, and 4), selecting **IMP 50** will generate the "OUT OF RANGE" error. For example, if you program the module to output 8 VDC from the module in the 0Ω mode, selecting **IMP 50** will generate an error. Similarly, if the present AC output voltage is generated in the 50Ω mode and is less than 0.03125 VPP (which is the smallest peak-to-peak voltage that can be generated in the 0Ω mode), selecting **IMP 0** will generate the "OUT OF RANGE" error.

Sine, ramp, square, and arbitrary waveforms generated in the 0Ω mode (**IMP 0**) may not drive 50Ω cables properly at frequencies greater than 100 kHz. Therefore, we recommend that you select the 50Ω mode (**IMP 50**) when driving 50Ω cables at frequencies greater than 100 kHz. Generating high-frequency waveforms with amplitudes greater than 10 VPP in the 0Ω mode may also cause the module's current-limited output to generate unpredictable waveforms.

The Autorange Function

You enable and disable the autorange function using the **ARANGE** command. When the autorange function is enabled (**ARANGE ON**), the module automatically selects the lowest voltage or current range which will provide maximum accuracy for the desired output level. An error is generated if you attempt to set the output level greater than 100% of the highest voltage or current range available. (For AC waveforms, an error is also generated if you attempt to set the peak-to-peak amplitude less than 10% of the lowest available peak-to-peak range.) When the autorange function is disabled (**ARANGE OFF**), the module retains the present range regardless of the programmed output value. If the programmed value attempts to exceed 100% of the present range, an error is generated. (For AC waveforms, an error is also generated if you attempt to set the peak-to-peak amplitude less than 10% of the present peak-to-peak range.)

At power-on, the autorange function is enabled. Autoranging is automatically enabled when commands which change the DC resolution mode (**DCRES** command), output impedance (**IMP** command), or output function (**ADJUST** and **APPLY** commands) are executed.

To disable autoranging on the module in the **USE** slot, send:

```
OUTPUT 709; "ARANGE OFF"
```

To enable autoranging, send:

```
OUTPUT 709; "ARANGE ON"
```

The **ARANGE?** query command returns "ON" or "OFF" indicating whether the autorange function is enabled or disabled on the module in the **USE** slot. The following program reads and displays the present autorange setting.

```
10 OUTPUT 709; "ARANGE?"
20 ENTER 709; A$
30 PRINT A$
40 END
```

Specifying the Output Range

The **RANGE** command allows you to select a specific output range or enable the autorange function. The command has the following syntax:

```
RANGE [max_output]
```

where *max_output* is the maximum output voltage or current to be programmed. After specifying the maximum expected output level, the module selects the lowest range which will generate the desired level. Tables 1 through 4 earlier in this manual show the voltage and current ranges available.

Since the output range values differ according to the DC resolution mode, output impedance, and output function selected (see Tables 1 through 4), the module automatically enables the autorange function when any of these output parameters are changed. Therefore, when selecting output ranges using the **RANGE** command, you should make the range selection **AFTER** the resolution mode, output impedance, and output function have been chosen. However, to avoid the "OUT OF RANGE" error, do not execute **RANGE** until you have checked to see that the desired output level can be generated on the desired range.

The following program shows how **RANGE** is used with the **APPLY DCV** command to select a DC voltage range. Line 10 resets the module to its power-on state and chooses the DC voltage function, high-resolution mode, and 0Ω output impedance mode (autorange is enabled). Line 20 specifies a maximum expected output voltage of 8 VDC (which selects the 10 VDC range). Line 30 generates 1.25 VDC on the 10 VDC range (since the output function is not changed from its power-on DC voltage function, the **RANGE** command can be executed following the **APPLY DCV** command). Refer to "Outputting DC Voltage" for more information on using the **APPLY DCV** command.

```
10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "RANGE 8"
30 OUTPUT 709; "APPLY DCV 1.25"
40 END
```

You may also enable the autorange function using the **RANGE** command. To enable autoranging (i.e., the equivalent of **ARANGE ON**), substitute the word "AUTO" for the **RANGE** command's *max__output* parameter or default the parameter as shown below:

```
OUTPUT 709; "RANGE AUTO"
or
OUTPUT 709; "RANGE"
```

The **RANGE?** query command returns the present output range or the range selected by the autorange function. The following program reads and displays the output range selected for use on the module in the **USE** slot.

```
10 OUTPUT 709; "RANGE?"
20 ENTER 709; A
30 PRINT A
40 END
```

Setting the Output Delay Time

The **DELAY** command enables you to specify a time interval during which the module's output is allowed to settle before the next command is executed. You can set the delay time from 0 to 9.99 seconds with 0.01 second resolution. At power-on, the delay time is set to 0.04 seconds.

The following program outputs two DC voltages with delays from the module in mainframe slot 200. The program outputs 5 VDC followed by a two-second delay and then outputs 2.5 VDC followed by a two-second delay.

```
10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "DELAY 2"
30 OUTPUT 709; "APPLY DCV 5"
40 OUTPUT 709; "APPLY DCV 2.5"
50 END
```

The **DELAY** command affects those commands which control the output function (**APPLY** and **ADJUST** commands), output range (**ARANGE** and **RANGE**), DC resolution (**DCRES**), and output impedance (**IMP**). When the module is operating in the DC triggered-sequence mode (**APPLY DCMEMI** and **APPLY DCMEMV**), only the first value in the sequence is delayed.

Default Delay Times

If you do not specify a delay time, the HP 34521 automatically determines a delay time (*default delay*) based on the present output function, output range, DC resolution, and output impedance. If the output function, range, resolution, or output impedance are changed without specifying a new delay, the default delay time is automatically updated based on the new selection. However, once you program a delay time using **DELAY**, the value does not change until you specify another value or reset the module. Table 6 shows the default delay times for all output functions.

NOTE

You may specify a delay time which is shorter than the default value. However, the resulting settling time may be too short to allow the module to meet its accuracy specifications for that output function.

Table 6. Default Delay Times

Change In:	Default Delay
Function	
High-Resolution DCV or DCI From Any Other Function	1 Second
All Other Function Changes	30 ms
Output Value	
In High-Resolution Mode	40 ms
In Low-Resolution Mode (on same range)	0
In DC Triggered-Sequence Mode (first value)	30 ms
In DC Triggered-Sequence Mode (after first value)	0
In All Other Modes	30 ms
DC Offset (Sine, Ramp, Square, and Arbitrary Only)	30 ms
Range	
In High-Resolution Mode	40 ms
In All Other Modes	30 ms
Output Impedance (Voltage Only)	
In High-Resolution Mode	40 ms
In All Other Modes	30 ms

Checking the Delay Time

The **DELAY?** query command returns the present delay time in seconds. If no delay has been programmed using the **DELAY** command, **DELAY?** returns the default delay time based on the values shown in Table 6. The following program reads and displays the delay time for the module in the **USE** slot.

```

10 OUTPUT 709; "DELAY?"
20 ENTER 709; A
30 PRINT A
40 END

```

Using the HP 34521

This section shows you how to operate the module. It consists of the following subsections:

- Monitoring the Source Module
- Outputting DC Voltage
- Outputting DC Current
- Outputting AC Voltage
- Triggering the Source Module
- AC Triggering Modes

NOTE

*Quick, accurate, electronic auto-calibration can be performed when the HP 34521 is used with its self-test fixture (HP 34521D) and the HP 34520 Multimeter Module. Executing **FTEST es42** performs the auto-calibration function on the HP 34521 (*e* represents the mainframe or extender number and *s* represents the slot number). Refer to the HP 3235 Service Manual for more information on using **FTEST**.*

Monitoring the Source Module

The **MON STATE** command enables you to monitor (on the optional control panel's display) the state of a particular plug-in module. For example, to monitor the state of the module installed in mainframe slot 200, send:

```
OUTPUT 709; "MON STATE 200"
```

Since the **MON STATE** command returns more information about the HP 34521 than will fit in the 40-character control panel display, you must scroll the display to the left or right to see the entire module state. For this discussion, we will divide the display into five groups as shown below (this is the information which is displayed when the module is in its power-on state):

```
(1) State 200;Source 0.000000E+00 DCV,  
(2) FREQ 1000.000 1000.000,DCOFF 0.00000E+00,DUTY 50.0,PANG 0.000,  
(3) RANGE 1.0,ARANGE ON,TERM FRONT,IMP 0,DCRES HIGH,  
(4) TRIGMODE OFF,TRIGIN HIGH,TRIGOUT OFF,SYNCOUT OFF,  
(5) REFIN INT,REFOUT OFF,DELAY 0.04
```

The first group gives the slot number (200), the module name (**Source**), the present output voltage or current level (0.000000E+00), and the output function (DCV). The second group gives the following information about the AC voltage function: high-trigger-level (or single) and low-trigger-level output frequencies (FREQ 1000.000 1000.000), DC offset voltage (DCOFF 0.00000E+00), duty cycle (DUTY 50.0), and phase angle (PANG 0.000). The third group gives the voltage or current range (RANGE 1.0), the autorange setting (ARANGE ON), the output terminal (TERM FRONT), the output impedance (IMP 0), and the DC resolution mode (DCRES HIGH). The fourth group gives the triggering mode (TRIGMODE OFF), the input trigger source (TRIGIN HIGH), the output trigger mode (TRIGOUT OFF), and the SYNC destination (SYNCOUT OFF). The fifth group gives the reference frequency input source (REFIN INT), the reference frequency output source (REFOUT OFF), and the output delay time (DELAY 0.04).

To shut off the monitoring mode, send:

```
OUTPUT 709; "MON OFF"
```

In addition to the **MON STATE** command, you can monitor the module's output level using the **OUTPUT?** query command. This command returns the last programmed output level (voltage or current) from the module in the **USE** slot. If remote-sensing is used, **OUTPUT?** returns the last value generated by the module in response to the **ADJUST** command. Refer to "DC Voltage, Triggered Sequence" or "DC Current, Triggered Sequence" for more information on using the **OUTPUT?** query command in the triggered sequence mode.

The following program reads and displays the last output level generated by the module in the **USE** slot.

```
10 OUTPUT 709; "OUTPUT?"
20 ENTER 709; A
30 PRINT A
40 END
```

Outputting DC Voltage

After selecting the module with the **USE** command, only one additional command is required to output DC voltage from the module. This command is **APPLY DCV** and has the following syntax:

APPLY DCV *volts*

where *volts* is the output voltage between -10.25 VDC and +10.25 VDC in the 0 Ω mode or between -5.125 VDC and +5.125 VDC in the 50 Ω mode (when terminated with a 50 Ω load). Tables 1 and 2 earlier in this manual show the DC voltage ranges available in the high- and low-resolution modes.

The following program outputs 3.5 VDC from the module in mainframe slot 200. The **RST** command places the module in its power-on state with the DC voltage function selected, autorange enabled, high-resolution mode enabled, output impedance set to 0 Ω , and front **OUTPUT** connector selected. For this example, the autorange function selects the high-resolution 10 VDC range.

```
10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "APPLY DCV 3.5"
30 END
```

The following program outputs -1.35 VDC from the module in mainframe slot 300 to analog bus 1 (AB1). The **RST** command initially places the module in its power-on state. Line 30 changes the output impedance from 0 Ω to 50 Ω . Line 40 outputs -1.35 VDC on the high-resolution 5 VDC range (if the module is not terminated with a 50 Ω load, the actual output voltage will depend on the value of the load). Lines 50 through 90 read and display the present output voltage range ("5") and autorange setting ("ON").

```

10 OUTPUT 709; "RST 300;USE 300"
20 OUTPUT 709; "TERM AB1"
30 OUTPUT 709; "IMP 50"
40 OUTPUT 709; "APPLY DCV -1.35"
50 OUTPUT 709; "RANGE?"
60 ENTER 709; A
70 OUTPUT 709; "ARANGE?"
80 ENTER 709; A$
90 PRINT A,A$
100 END

```

Selecting the DC Resolution Mode

The **DCRES** command selects the high- or low-resolution mode for DC voltage outputs from the module. In its power-on state, the module uses the high-resolution mode (**DCRES HIGH**) which offers two DC voltage ranges as shown in Table 1 earlier in this manual. The low-resolution mode (**DCRES LOW**) offers seven DC voltage ranges as shown in Table 2 earlier in this manual. Table 7 summarizes the two resolution modes.

Table 7. High-Resolution Mode vs. Low-Resolution Mode

High-Resolution Mode (DCRES HIGH)	Low-Resolution Mode (DCRES LOW)
Settling Time: 40 mS (at 0.0001% Resolution)	Settling Time: 100 μ S (at 0.05% Resolution)
6 Digits of Resolution	3 Digits of Resolution
2 DC Voltage Ranges	7 DC Voltage Ranges
Better Accuracy Specifications	Hardware Triggering is Available *

* Refer to "DC Voltage, Triggered Sequence" for more information.

At power-on, the high-resolution mode is selected. To change to the low-resolution mode, send:

```
OUTPUT 709; "DCRES LOW"
```

To return to the high-resolution mode, send:

```
OUTPUT 709; "DCRES HIGH"
```

The **DCRES?** query command returns "HIGH" or "LOW" indicating which resolution mode is selected for use on the module in the **USE** slot. The following program reads and displays the resolution mode selected.

```

10 OUTPUT 709; "DCRES?"
20 ENTER 709; A$
30 PRINT A$
40 END

```


DC Voltage, Triggered Sequence

The first part of this section described how to output a single DC voltage from the module using the **APPLY DCV** command. The module also has the ability to output a triggered sequence of low-resolution (i.e., **DCRES LOW**) DC voltages using the **APPLY DCMEMV** command. In the triggered-sequence mode, the module transfers voltage values from an HP 3235 array to the module and outputs them, one at a time, when triggers are received.

The **APPLY DCMEMV** command has the following syntax:

APPLY DCMEMV *length, array_name*

where *length* is the number of DC voltages to be output (the valid range is from 2 to 2048 values) and *array_name* is the name of the mainframe array containing the voltage values. This command automatically generates voltages using the low-resolution ranges shown in Table 2 earlier in this manual. Therefore, each value in *array_name* must be between -10 VDC and +10 VDC in the 0 Ω mode or between -5 VDC and +5 VDC in the 50 Ω mode. If the high-resolution mode (i.e., **DCRES HIGH**) is in effect when **APPLY DCMEMV** is executed, the module temporarily goes to the low-resolution mode. Any subsequent **APPLY DCI** or **APPLY DCV** command will return the module to the high-resolution mode.

When **APPLY DCMEMV** is executed, the voltage values are transferred from *array_name* to the module's internal storage buffer and the first voltage is output (a trigger is not required to output the first voltage). The remaining voltages are output, one at a time, when high-to-low triggers are received by the trigger event selected using the **TRIGIN** command. (Refer to "Triggering the Source Module" for more information.) After the last voltage in the array is output, the next trigger wraps around and outputs the first voltage.

If autorange is enabled, **APPLY DCMEMV** searches the first *length* elements of *array_name* to find the DC voltage with the largest magnitude (the **OUTPUT?** query command returns the magnitude of this DC voltage). It then selects the lowest voltage range which will provide maximum accuracy for the largest value in the array. If autorange is disabled, the module retains the range selected by **RANGE** and generates an error if any value in *array_name* attempts to exceed the present voltage range.

The following program outputs a triggered-sequence consisting of four voltages: -5.0, 0.0, 5.0, and 10.0 VDC. The **RST** command places the module in mainframe slot 200 in its power-on state with the DC voltage function selected, autorange enabled, output impedance set to 0 Ω , and front **OUTPUT** connector selected. When the program is executed, the **APPLY DCMEMV** command outputs the first value in the array (-5.0 VDC). The remaining voltages are output, one at a time, whenever the **TRIGIN SGL** command (a software trigger) is executed.

```
10  OUTPUT 709; "RST 200;USE 200"
20  OUTPUT 709; "DIM VOUT(3)"
30  OUTPUT 709; "FILL VOUT -5.0,0.0,5.0,10.0"
40  OUTPUT 709; "APPLY DCMEMV 4,VOUT"    !Output = -5.0
50  OUTPUT 709; "TRIGIN SGL"             !Output = 0.0
60  OUTPUT 709; "TRIGIN SGL"             !Output = 5.0
70  OUTPUT 709; "TRIGIN SGL"             !Output = 10.0
80  OUTPUT 709; "TRIGIN SGL"             !Output = -5.0 (wrap-around)
90  OUTPUT 709; "TRIGIN SGL"             !Output = 0.0
100 END
```

Output range values (selected by the **ARANGE**, **IMP**, or **RANGE** commands) which are specified after the **APPLY DCMEMV** command has been executed do not take effect until another **APPLY DCMEMV** command is executed. (**APPLY DCMEMV** retains the range which is selected at the time the voltage values are transferred to the module's internal storage buffer.) However, the **MON STATE** display and other query commands are updated as soon as the range values are changed.

Remote-Sensed DC Voltages

Remote-sensing is available for DC voltage outputs used in conjunction with the HP 34520 Multimeter to ensure that an accurate voltage is present at the load. This function is convenient for applications where you want to enhance the source module's voltage accuracy to equal the multimeter's accuracy plus the tolerance of the **ADJUST DCV** command. Remote-sensing is also useful for applications where the load current will degrade the source module's voltage accuracy or when the module is used to control an external device such as a voltage-programmed power supply.

The **ADJUST DCV** command has the following syntax:

ADJUST DCV *volts*, *dmm_slot#* [, *LIM upper*, *lower*] [, *tolerance* [, *count*]]

where *volts* is the desired voltage at the load, as measured by the multimeter, in the range -250 VDC to +250 VDC; *dmm_slot#* is the slot number (in the form *es00*) of the HP 34520 Multimeter selected for remote-sensing; *upper* and *lower* are optional upper and lower limits, in DC volts, for the voltage at the output of the source module (default is no upper and lower limits); *tolerance* defines the window, in DC volts, within which the voltage at the load will be considered valid by the multimeter (in the high-resolution mode, the default tolerance is 0.001% of *volts* or 10 μ V, whichever is greater; in the low-resolution mode, the default tolerance is 0.1% of *volts* or 1 mV, whichever is greater); and *count* is the number of attempts the source module will make to cause the load voltage to fall within *tolerance* before generating an error (default *count* is 10).

Before sending the **ADJUST DCV** command, the multimeter must be programmed to measure DC voltage with the desired speed and accuracy. The time required to execute **ADJUST DCV** depends on multimeter and source module parameters (integration time, delay time, autozero setting, etc.) as well as external circuit gain. For example, **ADJUST DCV** will take less time to converge on *volts* for a 1 PLC (power line cycle) setting on the multimeter than for a 10 PLC setting. Refer to the HP 34520 Programming and Configuration Manual for more information on using the multimeter.

The **ADJUST DCV** command will not work properly for circuits which start in saturation. To avoid this, the source module's output voltage should be preset using **APPLY DCV** such that the circuit output is not in or near saturation prior to the **ADJUST DCV** command. Upper and lower limits should be used to prevent saturation during the execution of **ADJUST DCV**.

NOTE

*When adjusting the voltage at the load to a value which causes the source module's output voltage to be near the top of a range, select the next highest range to ensure that **volts** can be reached.*

When **ADJUST DCV** is executed, the multimeter first measures the initial voltage present at the load. Then if necessary, the source module begins making adjustments to its output voltage such that the voltage measured at the load by the multimeter moves in the direction of *volts*. The source module continues to make adjustments to its output voltage until the voltage measured at the load by the multimeter falls within *tolerance* of *volts* or until *count* attempts are made. If any voltage output from the source module exceeds the *upper* or *lower* limits or if *count* is exceeded before *tolerance* is reached, an error is generated. Once an error is generated, the **ADJUST DCV** command is aborted and the voltage at the load remains at the level measured by the multimeter prior to the error.

When adjusting its output voltage, the source module does not generate an entirely new voltage with each attempt but rather adds voltage increments to its initial output voltage. Each voltage increment is calculated by dividing the difference between *volts* and the present voltage measured at the load by the external circuit gain. The external circuit gain is calculated by dividing the difference between the present and previous voltages measured at the load by the difference between the present and previous voltages output by the source module.

The following program generates an 8.5 VDC remote-sensed voltage using the HP 34520 Multimeter in slots 800/900 and the HP 34521 in slot 700. The **RST** command (line 10) places the modules in their respective power-on states. Line 30 sets the multimeter's measurement function to DC voltage. Line 50 generates 8.5 VDC, with a tolerance of 1 mV, at the point on the load being measured by the multimeter. The upper voltage limit for the source module is set to 9 VDC and the lower voltage limit is set to 0 VDC. Up to five attempts will be made by the source module to generate 8.5 VDC at the load. The **OUTPUT?** query command returns the last voltage generated by the source module in response to the **ADJUST DCV** command in line 50. For this example, the multimeter and source modules must be connected to the proper points on the load.

```
10 OUTPUT 709; "RST 700,800"
20 OUTPUT 709; "USE 800"
30 OUTPUT 709; "FUNC DCV"
40 OUTPUT 709; "USE 700"
50 OUTPUT 709; "ADJUST DCV 8.5,800,LIM 9,0,0.001,5"
60 OUTPUT 709; "OUTPUT?"
70 ENTER 709; A
80 PRINT A
90 END
```

The following program uses the **ADJUST DCV** command to adjust the output of an external device with gain to 40 VDC (the external device is assumed to have a gain of 10). The HP 34520 Multimeter in slots 800/900 and the HP 34521 in slot 700 are used in this example. The **RST** command (line 10) places the modules in their respective power-on states. Line 30 sets the multimeter's measurement

function to DC voltage. Line 50 will drive the external device to 40 VDC (the default *tolerance* of 10 μ V and default *count* of 10 are used for this example). The upper limit prevents the HP 34521 from driving the external device to output more than 50 VDC while adjusting to 40 VDC. The **OUTPUT?** query command returns the last voltage generated by the source module in response to the **ADJUST DCV** command in line 50. For this example, the multimeter and source modules must be connected to the proper points on the load.

```

10 OUTPUT 709; "RST 700,800"
20 OUTPUT 709; "USE 800"
30 OUTPUT 709; "FUNC DCV"
40 OUTPUT 709; "USE 700"
50 OUTPUT 709; "ADJUST DCV 40,800,LIM 5,0"
60 OUTPUT 709; "OUTPUT?"
70 ENTER 709; A
80 PRINT A
90 END

```

When using the HP 34521 to control external devices with gains less than 0.8, the **ADJUST DCV** command will generally require more than 10 attempts (the default number of attempts) to reach *volts*. Figure 3 shows the typical "worst case" number of attempts (*count* parameter) required to reach a desired output voltage at the load for external circuit gains less than unity.

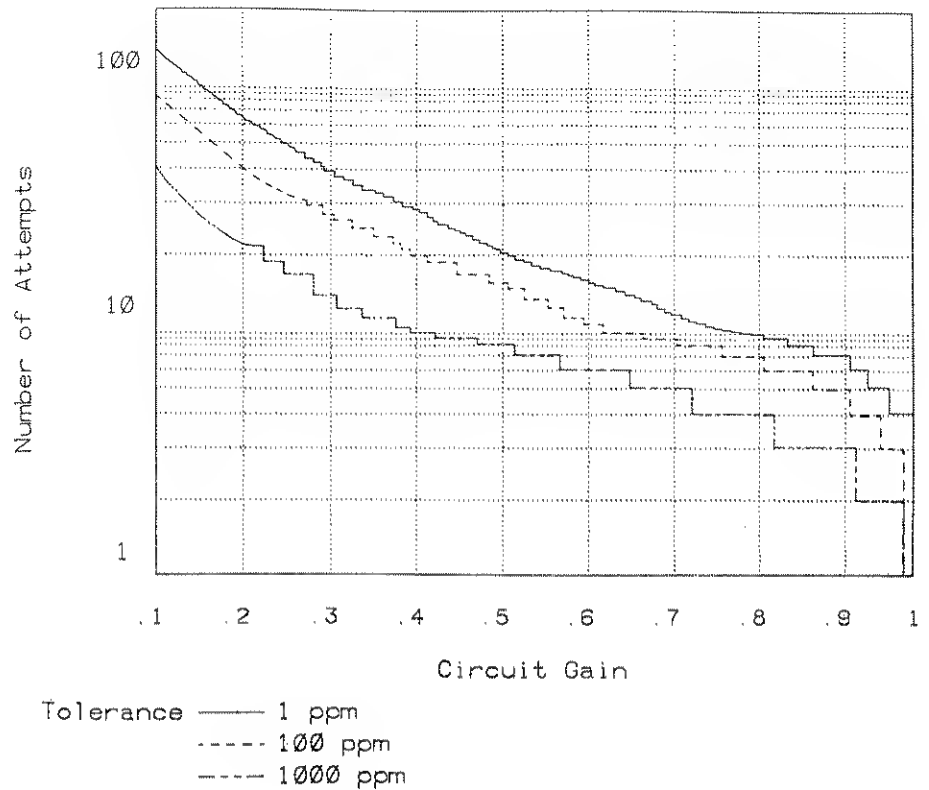
To reduce the number of attempts required, you can pre-program the source module to output a voltage such that the load voltage, to be measured by the multimeter, is near *volts* before executing the **ADJUST DCV** command. By presetting the source module's output voltage using the **APPLY DCV** command, **ADJUST DCV** is able to determine the external circuit gain more accurately. Therefore, the voltage at the load can be adjusted to the desired voltage using fewer attempts.

The following program shows how the **APPLY DCV** command can be used prior to the **ADJUST DCV** command to reduce the number of attempts required to reach the desired load voltage. For this example, it is assumed that the external circuit gain is 0.25 and the desired voltage at the load is 2.0 VDC. By setting the output voltage from the source module to 8 VDC using the **APPLY DCV** command (which will generate approximately 2 VDC at the load when the **ADJUST DCV** command is executed), the desired load voltage can be reached using fewer attempts.

```

10 OUTPUT 709; "RST 700,800"
20 OUTPUT 709; "USE 800"
30 OUTPUT 709; "FUNC DCV"
40 OUTPUT 709; "USE 700"
50 OUTPUT 709; "APPLY DCV 8"
60 OUTPUT 709; "ADJUST DCV 2,800"
70 OUTPUT 709; "OUTPUT?"
80 ENTER 709; A
90 PRINT A
100 END

```



3235P1/f. 21. 3

Figure 3. Number of Attempts vs. Circuit Gain (Gain < 1)

Outputting DC Current

After selecting the module with the **USE** command, only one additional command is required to output DC current from the module. This command is **APPLY DCI** and has the following syntax:

APPLY DCI *amps*

where *amps* is the output current between -0.1 ADC and +0.1 ADC in the high- or low-resolution mode. Table 3 earlier in this manual lists the DC current ranges available.

The following program outputs 3.25 mA from the module in mainframe slot 200. The **RST** command places the module in its power-on state with the DC voltage function selected, autorange enabled, high-resolution mode selected, and front OUTPUT connector selected. For this example, the autorange function selects the 0.01A range.

```
10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "APPLY DCI 3.25E-3"
30 END
```

The following program outputs 20 mA from the module in mainframe slot 300 to analog bus 1 (AB1). The **RST** command initially places the module in its power-on state. Line 30 outputs 20 mA on the 0.1A range. Lines 40 through 80 read and display the present range ("1.0000000E-01") and autorange setting ("ON").

```

10 OUTPUT 709; "RST 300;USE 300"
20 OUTPUT 709; "TERM AB1"
30 OUTPUT 709; "APPLY DCI 20E-3"
40 OUTPUT 709; "RANGE?"
50 ENTER 709; A$
60 OUTPUT 709; "ARANGE?"
70 ENTER 709; B$
80 PRINT A$,B$
90 END

```

Selecting the DC Resolution Mode

The **DCRES** command selects the high- or low-resolution mode for DC current outputs from the module. In its power-on state, the module uses the high-resolution mode. For DC current outputs, four ranges are available as shown in Table 3 earlier in this manual. Table 8 summarizes the two resolution modes.

Table 8. High-Resolution Mode vs. Low-Resolution Mode

High-Resolution Mode (DCRES HIGH)	Low-Resolution Mode (DCRES LOW)
Settling Time: 40 ms (at 0.0001% Resolution)	Settling Time: 100 μ s (at 0.05% Resolution)
6 Digits of Resolution	3 Digits of Resolution
4 DC Current Ranges	4 DC Current Ranges
Better Accuracy Specifications	Hardware Triggering is Available *

* Refer to "DC Current. Triggered Sequence" for more information.

At power-on, the high-resolution mode is selected. To change to the low-resolution mode, send:

```
OUTPUT 709; "DCRES LOW"
```

To return to the high-resolution mode, send:

```
OUTPUT 709; "DCRES HIGH"
```

The **DCRES?** query command returns "HIGH" or "LOW" indicating which resolution mode is selected for use on the module in the **USE** slot. The following program reads and displays the resolution mode selected.

```
10 OUTPUT 709; "DCRES?"
20 ENTER 709; A$
30 PRINT A$
40 END
```

DC Current, Triggered Sequence

The first part of this section described how to output a single DC current from the module using the **APPLY DCI** command. The module also has the ability to output a triggered sequence of low-resolution (i.e., **DCRES LOW**) DC currents using the **APPLY DCMEMI** command. In the triggered-sequence mode, the module transfers current values from an HP 3235 array to the module and outputs them, one at a time, when triggers are received.

The **APPLY DCMEMI** command has the following syntax:

APPLY DCMEMI *length, array_name*

where *length* is the number of currents to be output (the valid range is from 2 to 2048 values) and *array_name* is the name of the mainframe array containing the current values. This command automatically generates currents using the low-resolution values shown in Table 3 earlier in this manual. Each value in *array_name* must be between -0.1 ADC and +0.1 ADC. If the high-resolution mode (i.e., **DCRES HIGH**) is in effect when **APPLY DCMEMI** is executed, the module temporarily goes to the low-resolution mode. Any subsequent **APPLY DCI** or **APPLY DCV** command will return the module to the high-resolution mode.

When **APPLY DCMEMI** is executed, the currents are transferred from *array_name* to the module's internal storage buffer and the first current is output (a trigger is not required to output the first current). The remaining currents are output, one at a time, when high-to-low triggers are received by the trigger event selected using the **TRIGIN** command. (Refer to "Triggering the Source Module" for more information.) After the last current in the array is output, the next trigger wraps around and outputs the first current.

If autorange is enabled, **APPLY DCMEMI** searches the first *length* elements of *array_name* to find the DC current with the largest magnitude (the **OUTPUT?** query command returns the magnitude of this DC current). It then selects the lowest current range which will provide maximum accuracy for the largest value in the array. If autorange is disabled, the module retains the range selected by **RANGE** and generates an error if any value in *array_name* attempts to exceed the present range.

The following program outputs a triggered-sequence consisting of four currents: -0.05, +0.051, -0.052, and +0.053 ADC. The **RST** command places the module in mainframe slot 200 in its power-on state with the DC voltage function selected, autorange enabled, and front OUTPUT connector selected. When the program is executed, the **APPLY DCMEMI** command outputs the first value in the array (-0.05 ADC). The remaining currents are output, one at a time, whenever the **TRIGIN SGL** command (a software trigger) is executed.

```

10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "DIM IOUT(3)"
30 OUTPUT 709; "FILL IOUT -0.05,0.051,-0.052,0.053"
40 OUTPUT 709; "APPLY DCMEMI 4,IOUT" !Output = -0.05
50 OUTPUT 709; "TRIGIN SGL" !Output = +0.051
60 OUTPUT 709; "TRIGIN SGL" !Output = -0.052
70 OUTPUT 709; "TRIGIN SGL" !Output = +0.053
80 OUTPUT 709; "TRIGIN SGL" !Output = -0.05 (wrap-around)
90 OUTPUT 709; "TRIGIN SGL" !Output = +0.051
100 END

```

Output range values (selected by **ARANGE** or **RANGE**) which are specified after the **APPLY DCMEMI** command has been executed do not take effect until another **APPLY DCMEMI** command is executed. (**APPLY DCMEMI** retains the range which is selected at the time the current values are transferred to the module's internal storage buffer.) However, the **MON STATE** display and other query commands are updated as soon as the range values are changed.

Outputting AC Voltage

After selecting the module with the **USE** command, one of four commands can be used to generate sine, ramp, square, or arbitrary waveforms. The four **APPLY** commands which generate AC waveforms have the following syntax statements:

APPLY ACV *pp_amplitude* (Sine Waveform)

APPLY RPV *pp_amplitude* (Ramp Waveform)

APPLY SQV *pp_amplitude* (Square Waveform)

APPLY WFV *pp_amplitude* [, *array_name*] (Arbitrary Waveform)

where *pp_amplitude* is the peak-to-peak output amplitude between 0.03125 VPP and 20 VPP in the 0 Ω output impedance mode or between 0.015625 VPP and 10 VPP in the 50 Ω mode (when terminated with a 50 Ω load). Table 4 earlier in this manual lists the AC voltage ranges available. The peak-to-peak amplitude can be set from 10% to 100% of the selected range.

The optional *array_name* parameter used with the **APPLY WFV** command specifies the name of the HP 3235 array containing 2048 points which define the arbitrary waveform. Refer to "Generating Arbitrary Waveforms" for more information on using the **APPLY WFV** command.

The following program outputs a 4.5 VPP sine waveform from the module in mainframe slot 200. The **RST** command places the module in its power-on state with the DC voltage function selected, autorange enabled, output impedance set to 0 Ω , output frequency set to 1000 Hz, 0 VDC offset, and front OUTPUT connector selected. For this example, the autorange function selects the 5 VPP range.

```

10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "APPLY ACV 4.5"
30 END

```


The following program outputs a 1.35 VPP square waveform from the module in mainframe slot 300 to analog bus 1 (AB1). The **RST** command (line 10) initially places the module in its power-on state. Line 30 changes the output impedance from 0 Ω to 50 Ω . The program then outputs a 1.35 VPP square waveform from the 2.5 VPP range (if not terminated with a 50 Ω load, the actual output will depend on the load). Lines 50 through 90 read and display the present range ("2.5") and autorange function ("ON").

```

10 OUTPUT 709; "RST 300;USE 300"
20 OUTPUT 709; "TERM AB1"
30 OUTPUT 709; "IMP 50"
40 OUTPUT 709; "APPLY SQV 1.35"
50 OUTPUT 709; "RANGE?"
60 ENTER 709; A
70 OUTPUT 709; "ARANGE?"
80 ENTER 709; A$
90 PRINT A,A$
100 END

```

Specifying the Output Frequency

At power-on, the output frequency for sine, ramp, square, and arbitrary waveforms is set to 1000 Hz. You change the output frequency using the **FREQ** command. The output frequency for sine, square, and arbitrary waveforms can be varied from 0 to 1 MHz with 0.001 Hz resolution. Ramp waveform performance is not specified above 100 kHz and will degrade substantially above this frequency.

To set the output frequency to 5 kHz for example, send:

```

OUTPUT 709; "FREQ 5000"
or
OUTPUT 709; "FREQ 5E+3"

```

The **FREQ** command is also used in the dual-frequency mode which is discussed later in this manual. When used in this mode, the **FREQ** command uses two parameters to specify a high-trigger-level and low-trigger-level output frequency. Refer to "Generating Dual-Frequency AC Waveforms" for more information.

Generating a Frequency-Stepped Sweep

This subsection contains an example program which uses the **FREQ** command in an HP 3235 subroutine to perform a 100 Hz to 100 kHz frequency-stepped sweep. The subroutine outputs a 5 VPP sine waveform from the module in mainframe slot 200 and runs through the frequency range in 100 Hz steps (the step rate is approximately 600 Hz).

```

10 OUTPUT 709; "SUB SWEEP"
20 OUTPUT 709; "RST 200;USE 200"
30 OUTPUT 709; "APPLY ACV 5"
40 OUTPUT 709; "FOR I = 100 TO 100000 STEP 100"
50 OUTPUT 709; "FREQ I"
60 OUTPUT 709; "NEXT I"
70 OUTPUT 709; "SUBEND"
80 OUTPUT 709; "CALL SWEEP"
90 END

```

The previous example program generated a linear frequency-stepped sweep from a low frequency to a high frequency. You can easily modify the program to produce decreasing frequency, log, or other user-defined sweeps. Precomputing and storing the sweep frequencies in an HP 3235 array will maintain a high step rate.

Hardware control of the sweep is available using the HP 3235's interrupt system to pause the sweep subroutine or to modify variables effecting the sweep. Refer to Chapter 10 of the HP 3235 Programming and System Information Manual for more information on using interrupts.

Setting the DC Offset Voltage

At power-on, the DC offset voltage for sine, ramp, square, and arbitrary waveforms is 0 volts. You change the offset voltage using the **DCOFF** command. The offset can be a positive or negative number such that the peak AC value of the output waveform, plus the magnitude of the offset, does not exceed 50% of the selected peak-to-peak range. If the autorange function is enabled (**ARANGE ON** or **RANGE AUTO**), the module automatically changes range as required to accommodate the offset voltage.

NOTE

Care should be taken when selecting a DC offset which is larger than the waveform's peak-to-peak amplitude since this may result in a range selection which is too high to produce the desired amplitude (the amplitude must be set to at least 10% of range).

In the power-on 0 Ω output impedance mode (**IMP 0**), the actual DC offset voltage will equal the programmed value with or without load termination. However, in the 50 Ω mode (**IMP 50**), the actual offset voltage will equal the programmed value **ONLY** when the module is terminated with a 50 Ω load. For example, if you program the module for a 2V offset in the 50 Ω mode, the actual offset voltage will be 2V only when terminated with a 50 Ω load. If the load is removed and replaced with an open circuit, the offset voltage will double to 4V.

The following program outputs a 5 VPP ramp waveform with a 0V offset from the module in mainframe slot 200. When line 30 changes the offset to -1.5V, the module must use the 10 VPP range to accommodate the peak AC amplitude (2.5V peak) plus offset (-1.5V). Line 40 attempts to change the offset to +7.6V but generates an error since the output amplitude plus offset exceeds 50% of the 20 VPP range (which is the highest peak-to-peak voltage range available).

```
10  OUTPUT 709; "RST 200;USE 200"
20  OUTPUT 709; "APPLY RPV 5"
30  OUTPUT 709; "DCOFF -1.5"
40  OUTPUT 709; "DCOFF 7.6"
50  END
```

The following program outputs a 0.5 VPP sine waveform with a 0V offset from the module in mainframe slot 300. When line 30 changes the offset to 2.25V, the module must use the 5 VPP range to accommodate the peak AC amplitude (0.25V peak) plus offset (2.25V). Line 40 attempts to change the offset to 2.251V but generates an error. The module attempts to use the 10 VPP range but can't since the desired amplitude (0.5 VPP) is less than 10% of that range.

```

10 OUTPUT 709; "RST 300;USE 300"
20 OUTPUT 709; "APPLY ACV 0.5"
30 OUTPUT 709; "DCOFF 2.25"
40 OUTPUT 709; "DCOFF 2.251"
50 END

```

Setting the Duty Cycle

At power-on, the duty cycle for ramp and square waveforms is set to 50%. You vary the duty cycle (for ramp and square waveforms only) from 5% to 95% using the **DUTY** command. The duty cycle is variable for frequencies up to 100 kHz. When generating square waveforms at frequencies above 100 kHz, an error is generated if the duty cycle is set to a value other than 50% (i.e., **DUTY 50**). Figure 4 shows square and ramp waveforms with 5% and 95% duty cycles.

NOTE

*Repeated specification of the same duty cycle (e.g., **DUTY 15;DUTY 15**) will cause momentary (approximately 120 mS) irregularities in the waveform.*

The following program generates a 4.5 VPP square waveform with a 15% duty cycle from the module in mainframe slot 200. Line 30 sets the output frequency to 5 kHz. (Remember that if you are generating square waveforms at frequencies greater than 100 kHz, the duty cycle must be set to 50%.)

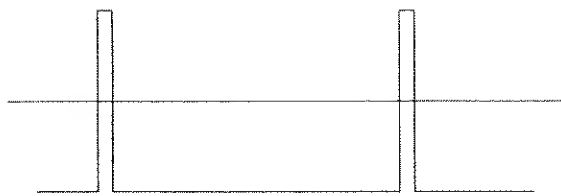
```

10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "DUTY 15"
30 OUTPUT 709; "FREQ 5E+3"
40 OUTPUT 709; "APPLY SQV 4.5"
50 END

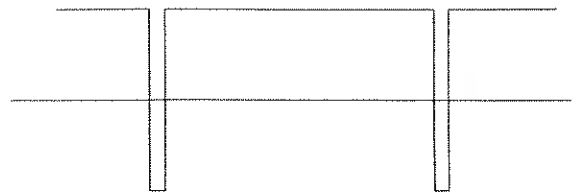
```

Selecting the SYNC Output Destination

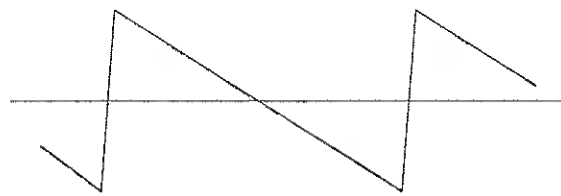
All AC waveforms (sine, ramp, square, and arbitrary) have an associated SYNC signal which is output to the module's front SYNC OUT connector when in operation. The SYNC signal is a logic "1" (+5V) when the waveform's output level is positive relative to its DC offset. The SYNC signal is a logic "0" (0V) when the waveform's output level is negative relative to its DC offset. Figure 5 shows a ramp waveform with its associated SYNC signal (the waveform is shown with a -2 VDC offset).



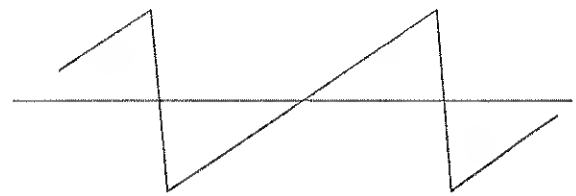
SQUARE WAVEFORM - 5% DUTY CYCLE



SQUARE WAVEFORM - 95% DUTY CYCLE



RAMP WAVEFORM - 5% DUTY CYCLE



RAMP WAVEFORM - 95% DUTY CYCLE

3235P1/F.21.4

Figure 4. Square and Ramp Waveform Duty Cycles

The SYNC signal is always routed to the module's front SYNC OUT connector but can also be routed to the HP 3235's trigger buses using the **SYNCOUT** command. The command has the following syntax:

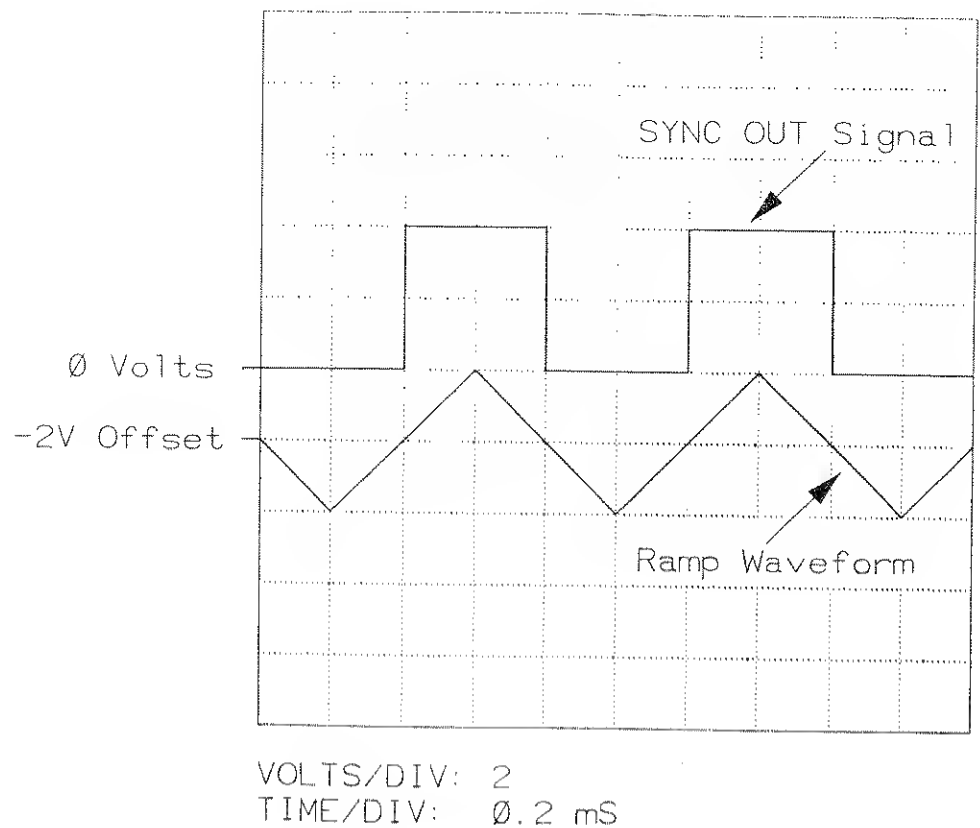
SYNCOUT destination

where *destination* is OFF, TB0, or TB1. At power-on, the destination is OFF (i.e., the SYNC signal is routed only to the SYNC OUT connector). To route the signal to trigger bus 1 as well as the SYNC OUT connector, send:

```
OUTPUT 709; "SYNCOUT TB1"
```

The **SYNCOUT?** query command returns "OFF", "TB0", or "TB1" indicating which SYNC destination has been selected. The following program reads and displays the selected SYNC destination for the module in the **USE** slot.

```
10 OUTPUT 709; "SYNCOUT?"
20 ENTER 709; A$
30 PRINT A$
40 END
```



3235PI/F.21.5

Figure 5. Ramp Waveform With SYNC OUT Signal

Remote-Sensed Sinewave Voltages

Remote-sensing is available for sinewave voltages used in conjunction with the HP 34520 Multimeter to ensure that an accurate voltage is present at the load. This function is convenient for applications where you want to enhance the source module's voltage accuracy to equal the multimeter's accuracy plus the tolerance of the **ADJUST DCV** command. Remote-sensing is also useful for applications where the load current will degrade the source module's voltage accuracy or when the module is used to control an external device with voltage gain or attenuation.

The **ADJUST ACV** command has the following syntax:

ADJUST ACV *volts*, *dmm_slot#* [, *LIM upper*, *lower*] [, *tolerance* [, *count*]]

where *volts* is the desired voltage at the load, as measured by the multimeter, in the range 0.001 VPP to 707 VPP (the maximum input to the HP 34520 is 250V AC RMS); *dmm_slot#* is the slot number (in the form *es00*) of the HP 34520 Multimeter selected for remote-sensing; *upper* and *lower* are optional upper and lower limits, in volts peak-to-peak, for the voltage at the output of the source module (default is no upper and lower limits); *tolerance* defines the window, in volts peak-to-peak, within which the voltage at the load will be considered valid by the multimeter (the default tolerance is 0.1% of *volts* or 1 mV, whichever is greater); and *count* is the number of attempts the source module will make to cause the load voltage to fall within *tolerance* before generating an error (default *count* is 10).

NOTE

*When specifying a value for **volts** in the **ADJUST ACV** command, you are specifying the desired load voltage in volts peak-to-peak. The HP 34520 Multimeter makes AC voltage measurements in volts RMS. The HP 3235 automatically makes the necessary conversions.*

Before sending the **ADJUST ACV** command, the multimeter must be programmed to measure AC voltage with the desired speed and accuracy. The time required to execute **ADJUST ACV** depends on multimeter and source module parameters (integration time, delay time, autozero setting, etc.) as well as external circuit gain. For example, **ADJUST ACV** will take less time to converge on **volts** for a 1 PLC (power line cycle) setting on the multimeter than for a 10 PLC setting. Refer to the HP 34520 Programming and Configuration Manual for more information on using the multimeter.

The **ADJUST ACV** command will not work properly for circuits which start in saturation. To avoid this, the source module's output voltage should be preset using **APPLY ACV** such that the circuit output is not in or near saturation prior to the **ADJUST ACV** command. Upper and lower limits should be used to prevent saturation during the execution of **ADJUST ACV**.

NOTE

*When adjusting the voltage at the load to a value which causes the source module's output voltage to be near the top of a range, select the next highest range to ensure that **volts** can be reached.*

When **ADJUST ACV** is executed, the multimeter first measures the initial voltage present at the load. Then if necessary, the source module begins making adjustments to its output voltage such that the voltage measured at the load by the multimeter moves in the direction of **volts**. The source module continues to make adjustments to its output voltage until the voltage measured at the load by the multimeter falls within *tolerance* of **volts** or until *count* attempts are made. If the source module's output voltage exceeds the *upper* or *lower* limits or if *count* is exceeded before *tolerance* is reached, an error is generated. Once an error is generated, the **ADJUST ACV** command is aborted and the voltage at the load remains at the level measured by the multimeter prior to the error.

When adjusting its output voltage, the source module does not generate an entirely new voltage with each attempt but rather adds voltage increments to its initial output voltage. Each voltage increment is calculated by dividing the difference between **volts** and the present voltage measured at the load by the external circuit gain. The external circuit gain is calculated by dividing the difference between the present and previous voltages measured at the load by the difference between the present and previous voltages output by the source module.

At power-on, the source module is placed in the DC voltage mode. Therefore, before generating remote-sensed sinewave voltages, the module must be placed in the AC voltage mode using the **APPLY ACV** command. By presetting the source module's output voltage using **APPLY ACV**, the **ADJUST ACV** command is also able to determine the external circuit gain more accurately. Therefore, the voltage at the load can be adjusted to the desired voltage using fewer attempts.

The following program generates a 4.5 VPP remote-sensed sinewave voltage using the HP 34520 Multimeter in slots 800/900 and the HP 34521 in slot 700. The **RST** command (line 10) places the modules in their respective power-on states. Line 30 sets the multimeter's measurement function to AC voltage. Line 50 places the source module in the AC voltage mode and outputs a 4 VPP sine waveform. Line 60 generates a remote-sensed 4.5 VPP sinewave, with a tolerance of 4 mVpp, at the point on the load being measured by the multimeter. The upper voltage limit for the source module is set to 5 VPP and the lower voltage limit is set to 0 VPP. Up to five attempts will be made by the source module to generate 4.5 VPP at the load. The **OUTPUT?** command returns the last voltage generated by the source module in response to the **ADJUST ACV** command in line 60. For this example, the multimeter and source modules must be connected to the proper points on the load.

```
10 OUTPUT 709; "RST 700,800"
20 OUTPUT 709; "USE 800"
30 OUTPUT 709; "FUNC ACV"
40 OUTPUT 709; "USE 700"
50 OUTPUT 709; "APPLY ACV 4"
60 OUTPUT 709; "ADJUST ACV 4.5,800,LIM 5,0,0.004,5"
70 OUTPUT 709; "OUTPUT?"
80 ENTER 709; A
90 PRINT
100 END
```

The following program uses the **ADJUST ACV** command to adjust the output from an external device with gain to 40 VPP (the external device is assumed to have a gain of 10). The HP 34520 Multimeter in slots 800/900 and the HP 34521 in slot 700 are used in this example. The **RST** command (line 10) places the modules in their respective power-on states. Line 30 sets the multimeter's measurement function to AC voltage. Line 50 places the source module in the AC voltage mode and outputs a 3.5 VPP sine waveform. Line 60 drives the external device to 40 VPP with a tolerance of 3 mVpp (the default *count* of 10 is used in this example). The upper limit prevents the HP 34521 from driving the external device to output more than 50 VPP while adjusting to 40 VPP. The **OUTPUT?** query command returns the last voltage generated by the source module in response to the **ADJUST ACV** command in line 60. For this example, the multimeter and source modules must be connected to the proper points on the load.

```

10 OUTPUT 709; "RST 700,800"
20 OUTPUT 709; "USE 800"
30 OUTPUT 709; "FUNC ACV"
40 OUTPUT 709; "USE 700"
50 OUTPUT 709; "APPLY ACV 3.5"
60 OUTPUT 709; "ADJUST ACV 40,800,LIM 5,0,0.003"
70 OUTPUT 709; "OUTPUT?"
80 ENTER 709; A
90 PRINT A
100 END

```

When using the HP 34521 to control external devices with gains less than 0.8, the **ADJUST ACV** command will generally require more than 10 attempts (the default number of attempts) to reach *volts*. Figure 6 shows the typical "worst case" number of attempts (*count* parameter) required to reach a desired output voltage at the load for external circuit gains less than unity.

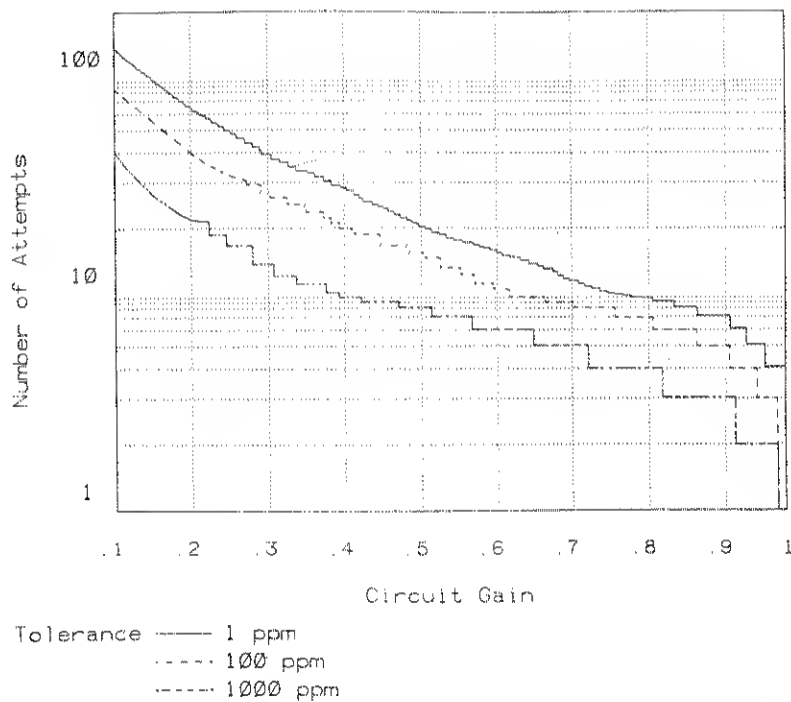


Figure 6. Number of Attempts vs. Circuit Gain (Gain < 1)

The following program shows how the **APPLY ACV** command can be used prior to the **ADJUST ACV** command to reduce the number of attempts required to reach the desired load voltage. For this example, it is assumed that the external circuit gain is 0.25 and the desired voltage at the load is 2.0 VPP. By setting the output voltage from the source module to 8 VPP using the **APPLY ACV** command (which will generate approximately 2 VPP at the load when the **ADJUST ACV** command is executed), the desired load voltage can be reached using fewer attempts.


```

10 OUTPUT 709; "RST 700,800"
20 OUTPUT 709; "USE 800"
30 OUTPUT 709; "FUNC ACV"
40 OUTPUT 709; "USE 700"
50 OUTPUT 709; "APPLY ACV 8"
60 OUTPUT 709; "ADJUST ACV 2,800"
70 OUTPUT 709; "OUTPUT?"
80 ENTER 709; A
90 PRINT A
100 END

```

Generating Arbitrary Waveforms

The **APPLY WFV** command generates arbitrary waveforms using 2048 points which you define and then store into an HP 3235 array. Each point is sampled at 4294967.296 Hz and is then low-pass-filtered at 1.25 MHz. This technique does not guarantee that each point is held the same length of time but does enable you to change the waveform's output frequency instantaneously using the **FREQ** command.

The **APPLY WFV** command has the following syntax:

```
APPLY WFV pp_amplitude [, array_name ]
```

where *pp_amplitude* is the peak-to-peak output amplitude between 0.03125 VPP and 20 VPP in the 0 Ω output impedance mode or between 0.015625 VPP and 10 VPP in the 50 Ω mode (when terminated with a 50 Ω load). The *array_name* parameter specifies the name of the mainframe real or integer array containing 2048 points which define the waveform. Each real array element must have a value between -1 and +1, inclusive.

NOTE

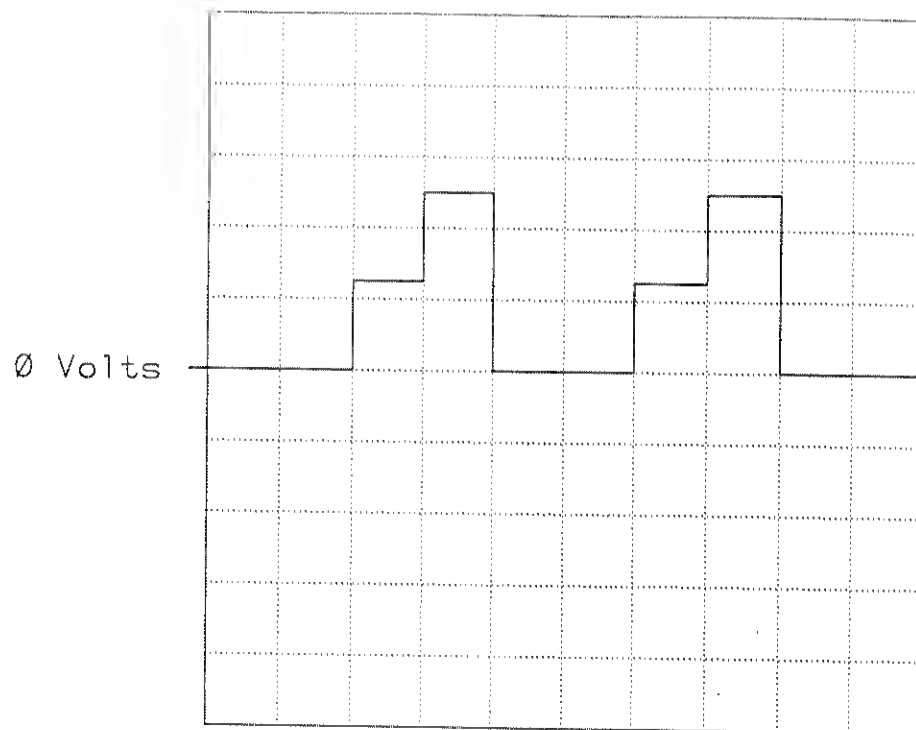
*If **array_name** is defined as an integer array, each element must be converted to a hardware integer format before executing the **APPLY WFV** command. Refer to "Precomputing AC Waveforms to Enhance Speed" for more information.*

The following program defines and generates a linear step waveform with a repetition rate of 5 kHz and a peak-to-peak amplitude of 5 VPP. Note that the array (STEP_ARRAY) is dimensioned as a real array with 2048 elements but only 1536 points are defined (elements 1536 through 2047 are set to 0). The waveform is generated on the 5 VPP range with autorange enabled, 0 Ω mode selected, and 0 VDC offset. Figure 7 shows the resulting output waveform.

```

10  OUTPUT 709; "RST 200;USE 200"
20  OUTPUT 709; "DIM STEP_ARRAY(2047)"
30  OUTPUT 709; "SUB ARB_STEP"
40  OUTPUT 709; "FOR I = 0 TO 511"
50  OUTPUT 709; "STEP_ARRAY(I) = 0"
60  OUTPUT 709; "NEXT I"
70  OUTPUT 709; "FOR I = 512 TO 1023"
80  OUTPUT 709; "STEP_ARRAY(I) = .5"
90  OUTPUT 709; "NEXT I"
100 OUTPUT 709; "FOR I = 1024 TO 1535"
110 OUTPUT 709; "STEP_ARRAY(I) = 1"
120 OUTPUT 709; "NEXT I"
130 OUTPUT 709; "SUBEND"
140 OUTPUT 709; "CALL ARB_STEP"
150 OUTPUT 709; "FREQ 5000"
160 OUTPUT 709; "APPLY WFV 5,STEP_ARRAY"
170 END

```



VOLTS/DIV: 1
TIME/DIV: 50 μS

3235P1/F.21.7

Figure 7. Linear Step Waveform

Since the **APPLY WFV** command's *array_name* parameter is optional, you can change the arbitrary waveform's peak-to-peak amplitude without re-downloading 2048 new points. For example, to change the output amplitude of the linear step waveform generated in the previous example from 5 VPP to 3.5 VPP, send:

```
OUTPUT 709; "APPLY WFV 3.5"
```

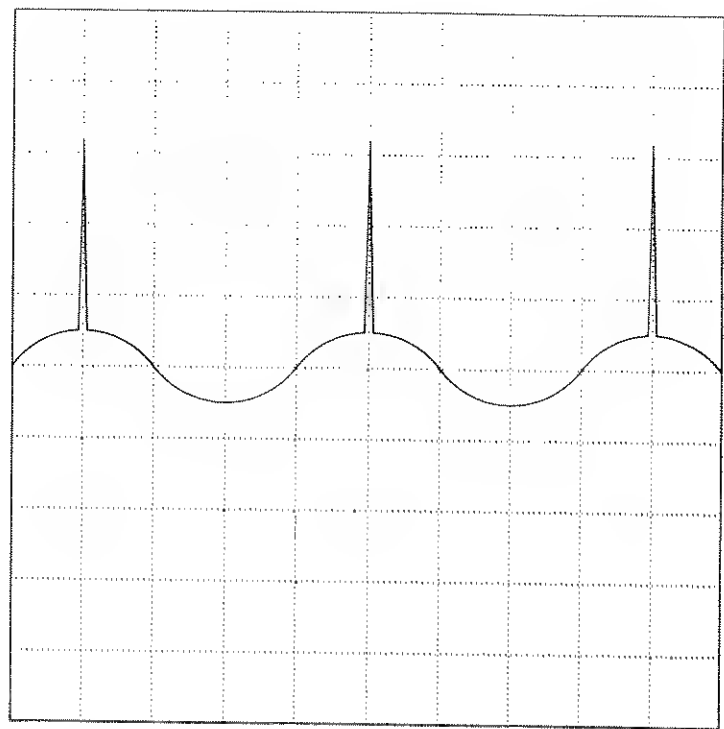
The following program defines and generates a 5 kHz sine waveform with voltage spikes on the positive peaks. The program first defines the sine waveform using all 2048 points and then redefines the appropriate points to add the voltage spikes. The waveform is generated on the 1.25 VPP range with autorange enabled, 0Ω mode selected, and 0 VDC offset. Figure 8 shows the resulting output waveform. (It takes approximately 15 seconds for the HP 3235 to generate this waveform.)

```
10  OUTPUT 709; "RST 200;USE 200"
20  OUTPUT 709; "REAL PI"
30  OUTPUT 709; "INTEGER I,J,WIDTH"
40  OUTPUT 709; "DIM CARRAY(2047)"
50  OUTPUT 709; "PI = 3.1415925"
60  OUTPUT 709; "SUB DEF_ARRAY"
70  OUTPUT 709; "  FOR I = 0 TO 2047"
80  OUTPUT 709; "    CARRAY(I) = 0.1*SIN(2*PI*I/2048)"
90  OUTPUT 709; "  NEXT I"
100 OUTPUT 709; "  WIDTH = 50"
110 OUTPUT 709; "  FOR J = 1 TO WIDTH"
120 OUTPUT 709; "    I = 512*WIDTH+J"
130 OUTPUT 709; "    CARRAY(I) = CARRAY(I) + 0.9*J/WIDTH"
140 OUTPUT 709; "  NEXT J"
150 OUTPUT 709; "  FOR J = 1 TO (WIDTH-1)"
160 OUTPUT 709; "    I = 512+WIDTH-J"
170 OUTPUT 709; "    CARRAY(I) = CARRAY(I) + 0.9*J/WIDTH"
180 OUTPUT 709; "  NEXT J"
190 OUTPUT 709; "SUBEND"
200 OUTPUT 709; "CALL DEF_ARRAY"
210 OUTPUT 709; "FREQ 5000"
220 OUTPUT 709; "APPLY WFV 1.2,CARRAY"
230  END
```

Pseudo-random noise can be generated as an arbitrary waveform or can be added to a previously defined arbitrary waveform using the HP Series 200/300 computer's **RND** command. The following program generates a Gaussian (normal distribution) noise pattern. (It takes approximately 30 seconds for the HP Series 200/300 computer to download this waveform.)

```
10  OUTPUT 709; "RST 200;USE 200"
20  OUTPUT 709; "DIM N(2047)"
30  FOR I = 0 TO 2047
40    OUTPUT 709; "N(;"I;") = "; 0.4*(RND+RND+RND+RND+RND)-1
50  NEXT I
60  OUTPUT 709; "FREQ 5"
70  OUTPUT 709; "APPLY WFV 2.5,N"
80  END
```

0 Volts



VOLTS/DIV: .2
TIME/DIV: 50 μ S

3235PI/F.21.8

Figure 8. Sine Waveform With Voltage Spikes

Reproducing a Digitized Waveform

This subsection contains an example program in which the HP 34521 reproduces a low-frequency (< 100 Hz) AC waveform which is digitized and stored by the HP 34520 Multimeter. In this example, it is assumed that the frequency of the waveform being digitized is 16 Hz and the source module reproduces the waveform at the same frequency. It is also assumed that the waveform is sampled 64 times by the multimeter. To digitize a waveform of any other frequency, you must modify the multimeter configuration and the array definitions in the program.

In the first section of the program, the multimeter is configured to measure DC voltage with the desired integration time and number of readings per trigger. The multimeter samples the input waveform 64 times and stores the digitized points in an HP 3235 array using the **MEM** command. For this example, the **NRDGS** command's **TIMER** parameter is used to specify a time interval between each of the 64 readings. To calculate the **TIMER** value, multiply the number of readings per trigger by the frequency of the input waveform and take the inverse of the result. For this example, the **TIMER** value is:

$$1/(64 \text{ rdgs per trigger} * 16 \text{ Hz}) = 1/1024 = 976\text{E}-6$$

In the second section of the program, the maximum and minimum values in the stored array are determined. The peak-to-peak amplitude and offset voltage are then calculated using these maximum and minimum values.

The waveform is reproduced by the source module in the last section of the program. The program uses a routine to expand each of the 64 digitized points into 32 new points by interpolation (64 digitized points multiplied by 32 expanded points per digitized point equals 2048 arbitrary waveform points). Although the frequency of the reproduced waveform is set to 16 Hz for this example, you can select any frequency up to 1 MHz. (It takes approximately 10 seconds for the HP 3235 to generate the digitized waveform.)

```

10  Multimeter = 800                !Define multimeter slot number
20  Source = 200                    !Define source slot number
30  !
40  !Configure the Multimeter Module and Digitize Input Waveform
50  !
60  OUTPUT 709; "SCRATCH"           !Scratch mainframe memory
70  OUTPUT 709; "RST";Multimeter    !Reset multimeter
80  OUTPUT 709; "USE";Multimeter    !Use multimeter in designated slot
90  OUTPUT 709; "DIM DMM(64)"       !Dimension HP 3235 array
100 OUTPUT 709; "NPLC 0.0005"       !Set integration time
110 OUTPUT 709; "AZERO OFF"         !Disable autozero mode
120 OUTPUT 709; "DELAY 0"           !Delay = 0 seconds
130 OUTPUT 709; "TBUFF OFF"         !Disable trigger buffering
140 OUTPUT 709; "FUNC DCV 5"        !Set measurement function and range
150 OUTPUT 709; "MEM OMM"           !Enable memory mode
160 OUTPUT 709; "NRDGS 64,TIMER"    !Take 64 readings per trigger
165                                !and store in mainframe array
170 OUTPUT 709; "TIMER 976E-6"      !Set timer value
180 OUTPUT 709; "TRIG SGL"          !Trigger the multimeter
190 OUTPUT 709; "MEM OFF"           !Disable memory mode
200 !
210 !Find Maximum and Minimum Values in Stored Array
220 !
230 OUTPUT 709; "SUB DIGITIZE"       !Beginning of Subroutine
240 OUTPUT 709; "REAL MAX,MIN,PP_AMP,OFFSET"
250 OUTPUT 709; "MAX = -250"
260 OUTPUT 709; "MIN = 250"
270 OUTPUT 709; "FOR I = 0 TO 63"
280 OUTPUT 709; "  IF DMM(I) > MAX THEN"
290 OUTPUT 709; "    MAX = DMM(I)"
300 OUTPUT 709; "  END IF"
310 OUTPUT 709; "  IF OMM(I) < MIN THEN"
320 OUTPUT 709; "    MIN = OMM(I)"
330 OUTPUT 709; "  END IF"
340 OUTPUT 709; "NEXT I"
350 !
360 !Compute Peak-to-Peak Amplitude and Offset Voltage
370 !
380 OUTPUT 709; "PP_AMP = MAX-MIN"
390 OUTPUT 709; "OFFSET = (MAX+MIN)/2"
400 !
410 !Reproduce Waveform Using APPLY WFV Command
420 !
430 OUTPUT 709; "DIM NEW_ARRAY(2047)"
440 OUTPUT 709; "FOR I = 0 TO 63"
450 OUTPUT 709; "NEW_ARRAY(32*I) = (DMM(I)-OFFSET)/(PP_AMP/2)"

```

```

460 OUTPUT 709; "FOR J = 1 TO 31"
470 OUTPUT 709; " IF I = 63 THEN"
480 OUTPUT 709; " DMM(I+1) = DMM(0)"
490 OUTPUT 709; " END IF"
500 OUTPUT 709; "NEW_ARRAY(32*I+J)=((J*(DMM(I+1)-DMM(I))/32+DMM(I))-
OFFSET)/(PP_AMP/2)"
510 OUTPUT 709; "NEXT J"
520 OUTPUT 709; "NEXT I"
530 OUTPUT 709; "RST";Source
540 OUTPUT 709; "USE"; Source
550 OUTPUT 709; "APPLY WFV PP_AMP,NEW_ARRAY;DCOFF OFFSET;FREQ 16"
560 !
570 OUTPUT 709; "SUBEND" !End of Subroutine
580 OUTPUT 709; "RUN DIGITIZE" !Execute Subroutine
590 END

```

Precomputing AC Waveforms to Enhance Speed

Whenever an **APPLY** command is used to generate a sine, ramp, square, or arbitrary waveform, the HP 3235 must download 2048 data points to the HP 34521. To arithmetically scale the data points into an integer format which the source module can use requires approximately 25 mS for sine waveforms, 95 mS for ramp waveforms, and 625 mS for arbitrary waveforms (real format). In addition to this scaling time, the source module requires approximately 50 mS to download the data points.

This subsection discusses three commands which you can use to decrease the time required to output a sine, ramp, or arbitrary waveform. These commands perform the scaling function on the waveforms and store precomputed values into a mainframe integer array. The values stored in the integer arrays are then output from the module using the **APPLY WFV** command (taking 50 ms). Although the higher-level **APPLY ACV** and **APPLY RPV** commands exist to generate sine and ramp waveforms, **APPLY WFV** is used to generate precomputed waveforms of all three types.

The three precompute commands have the following syntax (the module does not have the ability to precompute square waveforms):

```

FILLAC integer_array (Sine Waveform)
FILLRP integer_array [, %_duty] (Ramp Waveform)
FILLWF real_array, integer_array (Arbitrary Waveform)

```

where *integer_array* is the name of the mainframe integer array containing 2048 precomputed integer values; %_duty specifies the ramp waveform duty cycle between 5% and 95% (default is 50%); *real_array* is the name of the mainframe real array containing 2048 arbitrary waveform points which will be converted to integer format and stored in *integer_array*.

The following program precomputes and then applies a 10 kHz sine waveform with an amplitude of 5 VPP from the module in mainframe slot 200. Since autorange is enabled (power-on state), the module outputs the waveform on the 5 VPP range.

```
10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "INTEGER SCALE(2047)"
30 OUTPUT 709; "FILLAC SCALE"
40 OUTPUT 709; "FREQ 10E+3"
50 OUTPUT 709; "APPLY WFV 5,SCALE"
60 END
```

The following program precomputes and then applies a 3 kHz ramp waveform with an amplitude of 3.25 VPP from the module in mainframe slot 300. The waveform's duty cycle is set to 33%. Since autorange is enabled (power-on state), the module outputs the waveform on the 5 VPP range.

```
10 OUTPUT 709; "RST 300;USE 300"
20 OUTPUT 709; "INTEGER J(2047)"
30 OUTPUT 709; "FILLRP J,33"
40 OUTPUT 709; "FREQ 3000"
50 OUTPUT 709; "APPLY WFV 3.25,J"
60 END
```

The following program defines, precomputes, and then applies a 2 kHz cosine waveform with an amplitude of 2.3 VPP from the module in mainframe slot 400. Since autorange is enabled (power-on state), the module outputs the waveform on the 2.5 VPP range.

```
10 OUTPUT 709; "RST 400;USE 400"
20 OUTPUT 709; "DIM CARRAY(2047)"
30 OUTPUT 709; "REAL PI"
40 OUTPUT 709; "PI = 3.1415925"
50 OUTPUT 709; "SUB DEF_ARRAY"
60 OUTPUT 709; "FOR I = 0 TO 2047"
70 OUTPUT 709; "CARRAY(I) = COS(2*PI*I/2048)"
80 OUTPUT 709; "NEXT I"
90 OUTPUT 709; "SUBEND"
100 OUTPUT 709; "CALL DEF_ARRAY"
110 OUTPUT 709; "INTEGER J(2047)"
120 OUTPUT 709; "FILLWF CARRAY,J"
130 OUTPUT 709; "FREQ 2000"
140 OUTPUT 709; "APPLY WFV 2.3,J"
150 END
```

Triggering the Source Module

Selecting the Trigger Event

This subsection describes the various methods available for triggering the HP 34521. Triggering is used for generating DC voltage and DC current triggered sequences (**APPLY DCMEMV** and **APPLY DCMEMI** commands), synchronizing AC waveforms from multiple modules, gating AC waveforms on and off, and generating dual-frequency AC waveforms.

The **TRIGIN** command selects the event which is used to generate the trigger. The trigger events include signals on the HP 3235's trigger buses and the module's TRIGGER connector. In addition to these hardware trigger events, software triggers may also be generated. The **TRIGIN** command has the following syntax:

TRIGIN *event*

where *event* is one of the hardware or software trigger events described in Table 9. At power-on, **TRIGIN HIGH** is selected.

Table 9. TRIGIN Parameters

event Parameter	Definition
TB0	Trigger Bus 0. Trigger the module using the signal on backplane trigger bus 0.
TB1	Trigger Bus 1. Trigger the module using the signal on backplane trigger bus 1.
EXT	TRIGGER Connector. Trigger the module using the signal on the module's TRIGGER connector.
EXTBAR	Inverse of EXT. Trigger the module using the inverse of the signal on the module's TRIGGER connector.
LOW	Low Signal - Software Control. This parameter is used in conjunction with the HIGH parameter to internally trigger the module.
HIGH	High Signal - Software Control. This parameter is used in conjunction with the LOW parameter to internally trigger the module.
HOLD	Same as HIGH parameter.
SGL	Single Trigger. Assure a HIGH then change to LOW and then back to HIGH.

The **TRIGIN?** query command returns "TB0", "TB1", "EXT", "EXTBAR", "LOW", or "HIGH" indicating which trigger event is selected. (If **TRIGIN HOLD** or **TRIGIN SGL** are selected, "HIGH" is returned.) The following program reads and displays the trigger event selected for the module in the **USE** slot.

```
10 OUTPUT 709; "TRIGIN?"
20 ENTER 709; A$
30 PRINT A$
40 END
```

Driving the TRIGGER Connector

As described in the previous subsection, the **TRIGIN** command selects the module's trigger event. When the module is to be triggered using the HIGH, LOW, HOLD, or SGL software trigger events, that trigger signal may also be routed to the module's TRIGGER connector. The TRIGGER connector is enabled and disabled using the **TRIGOUT** command.

At power-on, outputs from the TRIGGER connector are disabled. To enable trigger signal outputs from the connector, send:

```
OUTPUT 709; "TRIGOUT EXT"
```

To disable outputs from the TRIGGER connector, send:

```
OUTPUT 709; "TRIGOUT OFF"
```

Outputs from the TRIGGER connector are automatically disabled when any of the **TRIGIN** command's hardware trigger events (TB0, TB1, EXT, or EXTBAR) are selected. Similarly, if one of the **TRIGIN** command's hardware events are selected and then **TRIGOUT EXT** is selected, **TRIGIN** is automatically set to HIGH.

The **TRIGOUT?** query command returns "EXT" or "OFF" indicating whether outputs from the TRIGGER connector are enabled or disabled. The following program reads and displays the status of the TRIGGER connector on the module in the **USE** slot.

```
10 OUTPUT 709; "TRIGOUT?"
20 ENTER 709; A$
30 PRINT A$
40 END
```

AC Triggering Modes

This section describes three AC triggering modes which are available for use with the HP 34521. These triggering modes include synchronizing waveforms from multiple modules, gating AC waveforms on or off, and generating dual-frequency waveforms from a single module.

Synchronizing Multiple AC Waveforms

This subsection describes how to synchronize sine, ramp, square, and arbitrary waveforms from multiple HP 34521 modules. This mode is convenient for generating multi-phase AC waveforms and precise harmonics.

In the synchronized mode, one source module is designated as a "master" and one or more source modules are designated as "slaves". Each module (master or slave) generates a reference frequency (1073741.824 Hz) based on its internal reference oscillator. In the synchronized mode, each slave's oscillator locks onto the reference frequency generated by the master. When the master and the slaves

are triggered (all modules must be triggered at the same time), each module begins outputting its waveform at the selected frequency and phase angle. Figure 9 shows a block diagram of a master linked to two slaves.

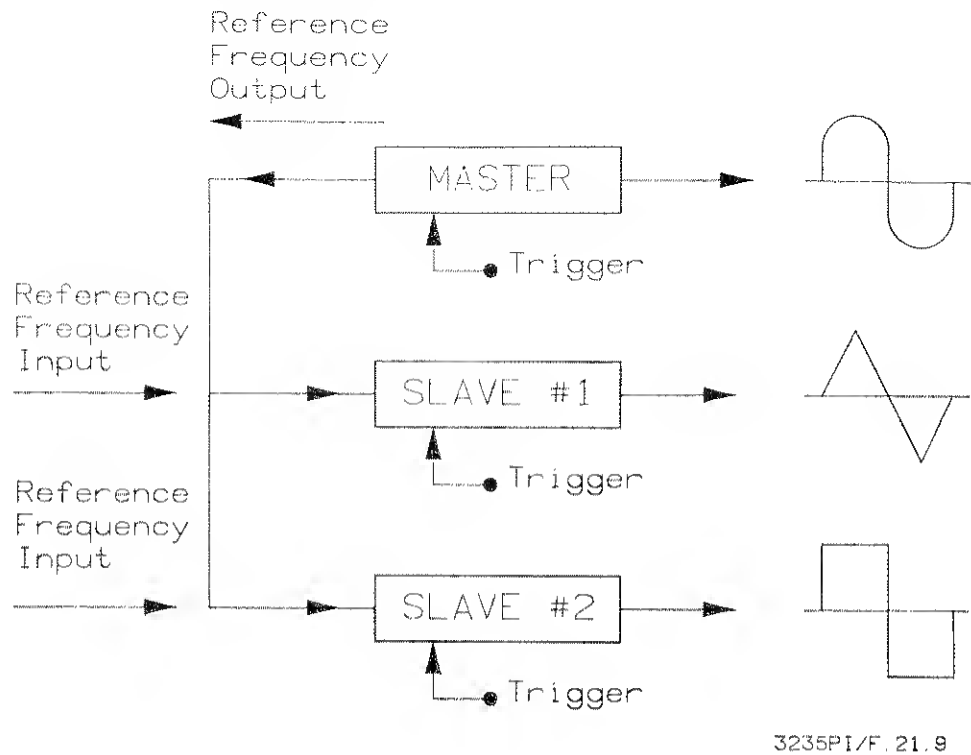


Figure 9. Synchronized Mode Block Diagram

Selecting the Reference Frequency Output Destination (Master Module)

The master's reference frequency can be routed to the slaves via the master's front FREQ REF connector, the HP 3235 trigger buses, or both. The **REFOUT** command selects the destination to which the module (the master) in the **USE** slot will output its reference frequency. The **REFOUT** command has the following syntax:

REFOUT *destination*

Table 10 lists the *destination* parameters and their definitions. At power-on, the reference frequency output destinations are disabled (**REFOUT OFF**) and the FREQ REF connector is placed in a high-impedance state.

Table 10. REFOUT Parameters

destination Parameter	Definition
OFF	Disable reference frequency output from master. Places FREQ REF connector in high impedance state.
EXT	FREQ REF Connector. Output reference frequency to the module's FREQ REF connector.
TB0	Trigger Bus 0. Output reference frequency from master to trigger bus 0.
TB1	Trigger Bus 1. Output reference frequency from master to trigger bus 1.
EXT TB0	Output reference frequency to the module's FREQ REF connector and to trigger bus 0.
EXT TB1	Output reference frequency to the module's FREQ REF connector and to trigger bus 1.

A single module is not allowed to both generate and receive the reference frequency signal. That is, a module cannot be a master and a slave at the same time. Therefore, whenever the **REFOUT** command is executed with any parameter other than **OFF**, that module's input reference frequency source is automatically set to internal (**REFIN INT**). Refer to "Selecting the Reference Frequency Input Source" for more information on using the **REFIN** command.

NOTE

Never connect FREQ REF connectors between two or more modules configured as masters. Doing so will cause conflict between active outputs and may deteriorate output waveform quality.

The **REFOUT?** query command returns a string indicating which reference frequency output destination is selected for the module in the **USE** slot. The command returns "OFF", "EXT", "TB0", "TB1", "EXT TB0", or "EXT TB1". The following program reads and displays the present output destination.

```

10 OUTPUT 709; "REFOUT?"
20 ENTER 709; A$
30 PRINT A$
40 END

```

Selecting the Reference Frequency Input Source (Slave Module)

As described in the previous section, the **REFOUT** command selects the destination to which the master routes its reference frequency to the slaves. The **REFIN** command selects the source from which the slave's reference oscillator will accept the reference frequency. The **REFIN** command has the following syntax:

REFIN *source*

As shown in Table 11, the *source* parameter choices include the slave's own internal reference frequency, the **FREQ REF** connector, and the HP 3235's trigger buses. At power-on, **REFIN INT** is selected which enables the slave to use its internal 1.07 MHz reference frequency and eliminates the need for a master.

Table 11. REFIN Parameters

source Parameter	Definition
INT	Internal. Use slave's internal 1.07 MHz* signal as reference frequency input source.
EXT	FREQ REF Connector. Use signal on slave's FREQ REF connector as reference frequency input source.
TB0	Trigger Bus 0. Use signal on trigger bus 0 as reference frequency input source.
TB1	Trigger Bus 1. Use signal on trigger bus 1 as reference frequency input source.

* Actual Frequency = 1073741.824 Hz, ± 50 ppm; TTL Levels.

A single module is not allowed to both generate and receive the reference frequency signal. That is, a module cannot be a master and a slave at the same time. Therefore, whenever the **REFIN** command is executed with any parameter other than **INT**, that module's output reference frequency source is automatically disabled (**REFOUT OFF**).

The **REFIN?** query command returns "INT", "EXT", "TB0", or "TB1" indicating which reference frequency input source is selected for the module in the **USE** slot. The following program reads and displays the present input source.

```

10 OUTPUT 709; "REFIN?"
20 ENTER 709; A$
30 PRINT A$
40 END

```

Setting the Phase Angle

At power-on, the phase angle for sine, ramp, square, and arbitrary waveforms is set to 0 degrees. In the synchronized mode, you change the phase angle (i.e., create a phase difference between multiple modules) using the **PANG** command which has the following syntax:

PANG *degrees*

where *degrees* is the phase angle between -360 degrees and +360 degrees with 0.001 degree resolution. Zero degrees is defined as the positive-going, zero-crossing point on the sine, ramp, or square waveform (relative to the DC offset). For arbitrary waveforms, zero degrees is defined as the first of the 2048 points required to define the waveform. One complete waveform equals 360 degrees.

To set the phase angle of the module in the **USE** slot to 45 degrees, send:

```
OUTPUT 709; "PANG 45"
```

The square waveform output and the SYNC signal for sine, ramp, square, and arbitrary waveforms are generated using analog zero-crossing circuitry. Setting the phase angle too close to zero degrees will generate an indeterminate output level prior to triggering the module in the synchronized mode (**TRIGMODE ARMWF** command). To guarantee that **PANG** will produce the desired output level prior to triggering, the phase angle should be set to at least 10 degrees from the zero-crossing phase for sine and square waveforms. For example, **PANG 0** on a sine waveform may produce low or high SYNC signal. However, **PANG -10** always produces low SYNC signal and **PANG 10** always produces high SYNC signal. Waveforms with lower zero-crossing slew rates will require larger phase correction.

Enabling the Synchronized Mode

After selecting the master's output source (**REFOUT** command), the slaves' input sources (**REFIN** command), and the phase angle (**PANG** command) the synchronized mode must be enabled using the **TRIGMODE ARMWF** command.

After enabling the synchronized mode using **TRIGMODE ARMWF**, an **APPLY** command sets the waveform (sine, ramp, square, or arbitrary) to its assigned output frequency (**FREQ** command) and phase angle (**PANG** command). When the master and the slaves are triggered, each module begins outputting its waveform (all modules must be triggered at the same time).

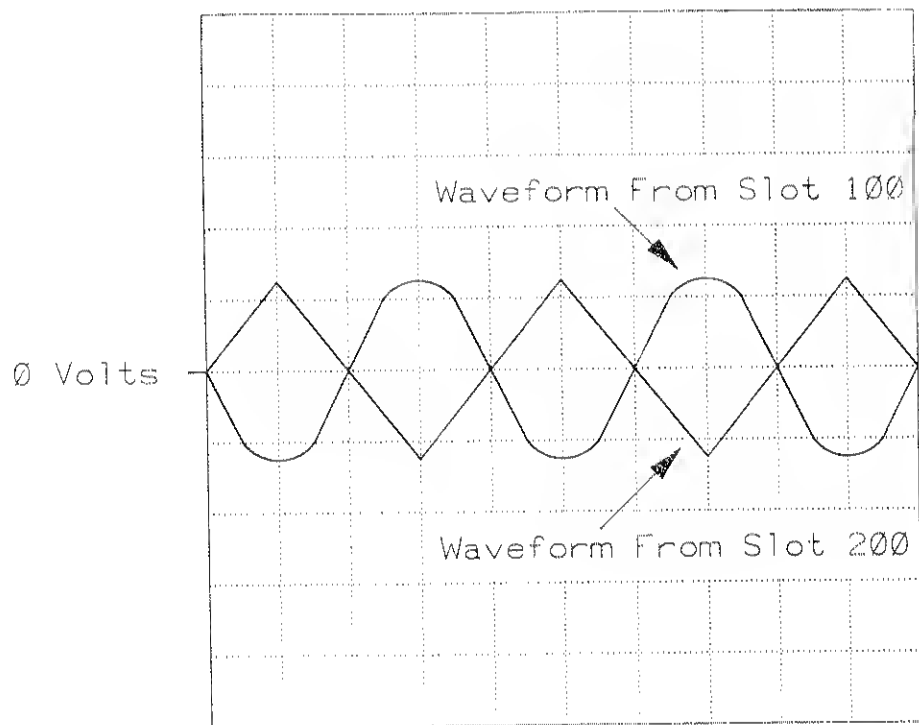
At power-on, the synchronized mode is disabled (**TRIGMODE OFF**). That is, the master and the slaves begin generating their AC waveforms as soon as an **APPLY** command is executed (a trigger is not required).

In the synchronized mode, the following commands reset the waveforms from the master and slaves to their starting phases: **ADJUST** commands, **APPLY** commands, **ARANGE ON**, **DCOFF**, **DUTY**, **FREQ**, **IMP**, **PANG**, **RANGE**, and **TRIGMODE ARMWF**. After one of these commands is executed, the waveform returns to its assigned phase angle and waits for another trigger before resuming. (Sending an **ARANGE**, **IMP**, or **RANGE** command to the same range will not reset the waveforms to their starting phase.)

Synchronized Mode Example Programs

The following program outputs a 5 VPP sine waveform (phase = 0°) from the master in slot 100 and a 5 VPP ramp waveform (phase = 180°) from the slave in slot 200. The master's reference frequency source is output to its FREQ REF connector (REFOUT EXT) and the slave accepts the reference frequency on its FREQ REF connector (REFIN EXT). For this example, the FREQ REF connectors must be connected between the master and slave. When a high-to-low signal is generated on trigger bus 0, the master and the slave begin generating waveforms at the selected frequency (5 kHz) and assigned phase angle. Figure 10 shows the resulting output waveforms.

```
10 OUTPUT 709; "RST 100,200;DRIVETBO HIGH"
20 OUTPUT 709; "USE 100;REFOUT EXT;TRIGMODE ARMWF;TRIGIN TBO"
30 OUTPUT 709; "USE 200;REFIN EXT;TRIGMODE ARMWF;TRIGIN TBO"
40 OUTPUT 709; "USE 100;FREQ 5000;PANG 0;APPLY ACV 5"
50 OUTPUT 709; "USE 200;FREQ 5000;PANG 180;APPLY RPV 5"
60 OUTPUT 709; "DRIVETBO LOW;DRIVETBO HIGH"
70 END
```



VOLTS/DIV: 2
TIME/DIV: 50 μ S

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Figure 10. Synchronized Mode Example Output

The following program generates the same waveforms as the previous example but uses a different method to trigger the modules. In this example, the master is triggered using the **TRIGIN** command's HIGH and LOW parameters. The master routes its trigger signal to its TRIGGER connector using the **TRIGOUT** command, which then triggers the slave. For this example, the TRIGGER connectors and the FREQ REF connectors must be connected between the master and the slave.

```

10  OUTPUT 709; "RST 100,200"
20  OUTPUT 709; "USE 100;TRIGIN HIGH"
30  OUTPUT 709; "REFOUT EXT;TRIGMODE ARMWF;TRIGOUT EXT"
40  OUTPUT 709; "USE 200;REFIN EXT;TRIGMODE ARMWF;TRIGIN EXT"
50  OUTPUT 709; "USE 100;FREQ 5000;PANG 0;APPLY ACV 5"
60  OUTPUT 709; "USE 200;FREQ 5000;PANG 180;APPLY RPV 5"
70  OUTPUT 709; "USE 100;TRIGIN LOW;TRIGIN HIGH"
80  END

```

The following program generates a 500 Hz sine waveform from the master in slot 300, a 1000 Hz sine waveform from the slave in mainframe slot 400, and a 1000 Hz square waveform from the slave in mainframe slot 500. The master's reference frequency source is output to trigger bus 0 (**REFOUT TB0**) and the slaves accept their reference frequencies on trigger bus 0 (**REFIN TB0**). When a high-to-low signal (generated external to the three modules) is detected on the TRIGGER connectors, the master and slaves begin generating their waveforms. For this example, the TRIGGER connectors must be connected between the master, slaves, and external trigger source.

```

10  OUTPUT 709; "RST 300,500"
20  OUTPUT 709; "USE 300;REFOUT TB0;TRIGMODE ARMWF;TRIGIN EXT"
30  OUTPUT 709; "USE 400;REFIN TB0;TRIGMODE ARMWF;TRIGIN EXT"
40  OUTPUT 709; "USE 500;REFIN TB0;TRIGMODE ARMWF;TRIGIN EXT"
50  OUTPUT 709; "USE 300;FREQ 500;APPLY ACV 5"
60  OUTPUT 709; "USE 400;FREQ 1000;APPLY ACV 5"
70  OUTPUT 709; "USE 500;FREQ 1000;APPLY SQV 5"
80  END

```

Gating AC Waveforms

This subsection describes how to gate sine, ramp, square, and arbitrary waveforms on or off. This function is convenient for generating waveforms which must start and stop at precisely the zero phase point.

The gated mode is enabled using the **TRIGMODE GATE** command. After enabling the gated mode, an **APPLY** command sets the designated waveform (sine, ramp, square, or arbitrary) to its assigned frequency (**FREQ** command). When the signal on the trigger event selected by the **TRIGIN** command is low (0V), the module generates an output. When the trigger signal returns high (+5V), the waveform continues until it reaches its zero phase point where it stops.

Zero phase is defined as the positive-going, zero-crossing point of the sine, ramp, or square waveform (relative to the DC offset). For arbitrary waveforms, zero degrees is defined as the first of the 2048 points required to define the waveform. At power-on, the gated mode is disabled (**TRIGMODE OFF**) and the module continuously generates its waveform (no trigger is required).

The following program enables the gated mode on the module in mainframe slot 200. When the signal on the module's front TRIGGER connector is low (0V), the module outputs a 2 kHz ramp waveform with a 20% duty cycle. When the signal returns high (+5V), the ramp waveform continues until it reaches its zero phase point where it stops. The resulting output is shown in Figure 11.

```

10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "TRIGMODE GATE"
30 OUTPUT 709; "TRIGIN EXT"
40 OUTPUT 709; "FREQ 2000"
50 OUTPUT 709; "DUTY 20"
60 OUTPUT 709; "APPLY RPV 5"
70 END

```

You can also use the **TRIGMODE GATE** command to generate a multi-period burst of a waveform by externally programming the gate pulse width to be N plus one-half periods long (where N is an integer number of periods). The following program uses an HP 3235 subroutine to generate a 3.5 mS trigger input. This is 3.5 periods of a 1 kHz output (1 periods equals 1 mS) and produces a four-period burst.

```

10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "TRIGMODE GATE"
30 OUTPUT 709; "FREQ 1000"
40 OUTPUT 709; "APPLY ACV 5"
50 OUTPUT 709; "SUB BURST"
60 OUTPUT 709; "TRIGIN LOW"
70 OUTPUT 709; "WAIT 3.5E-3"
80 OUTPUT 709; "TRIGIN HIGH"
90 OUTPUT 709; "SUBEND"
100 OUTPUT 709; "RUN BURST"
110 END

```

Generating Dual-Frequency AC Waveforms

This subsection describes how to modulate an AC waveform between two frequencies. This function is convenient for generating precise frequency changes or for holding the waveform at a specific frequency determined by the logic level of the selected trigger event.

The dual-frequency mode is enabled using the **TRIGMODE DUALFR** command. The two output frequencies are selected using the **FREQ** command (see also "Specifying the Output Frequency") which has the following syntax when used in the dual-frequency mode:

FREQ *freq_1, freq_2*

where *freq_1* is the output frequency generated when the signal on the trigger event selected by the **TRIGIN** command is high (+5V) and *freq_2* is the output frequency generated when the trigger event is low (0V). For sine, square, and arbitrary waveforms, both frequencies must be in the range 0 to 1 MHz. For ramp waveforms, both frequencies must be in the range 0 to 100 kHz. At power-on, both frequencies are set to 1000 Hz for all AC waveforms. Once the dual-frequency mode is selected and the output frequencies are set, an **APPLY** command sets the output frequency based on the trigger level. At power-on, the dual-frequency mode is disabled (**TRIGMODE OFF**) and the module outputs only the frequency selected by the **FREQ** command's *freq_1* parameter.

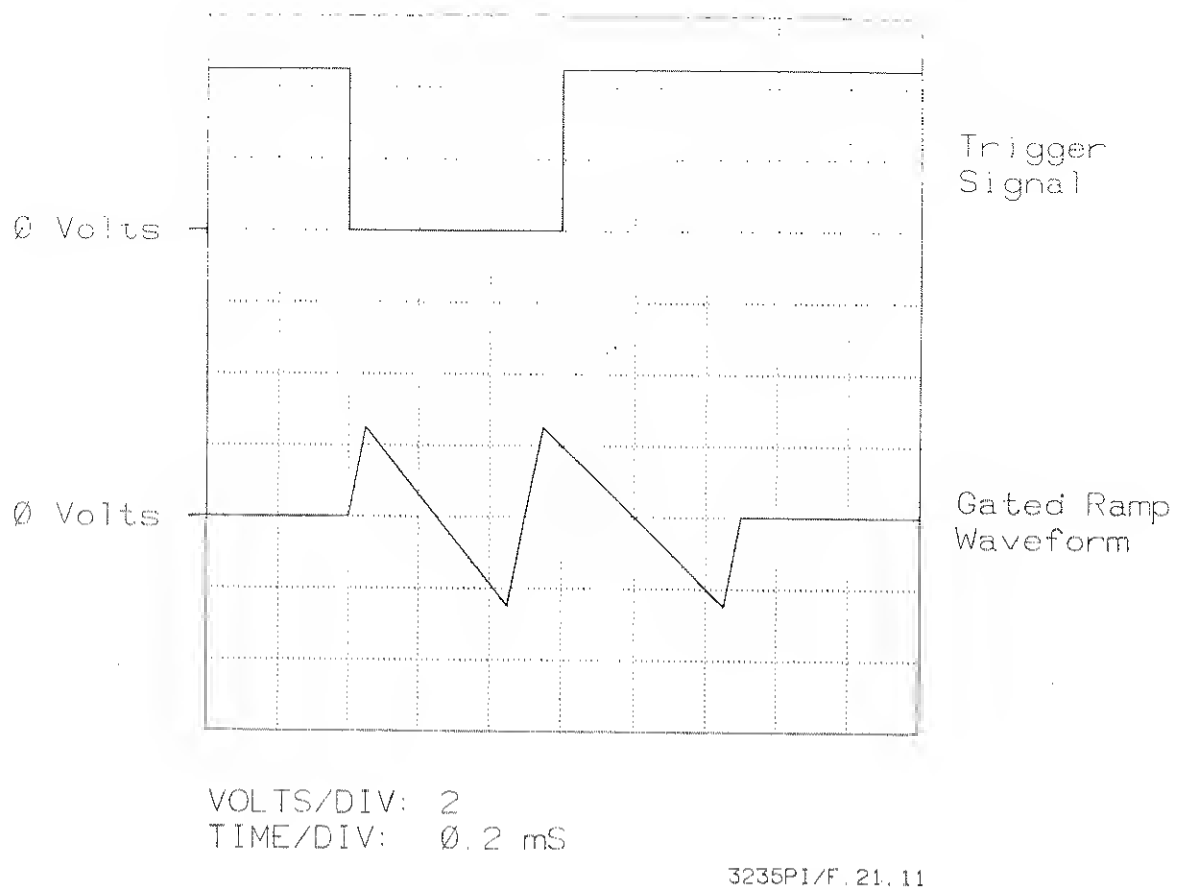


Figure 11. Gated Waveform Example Output

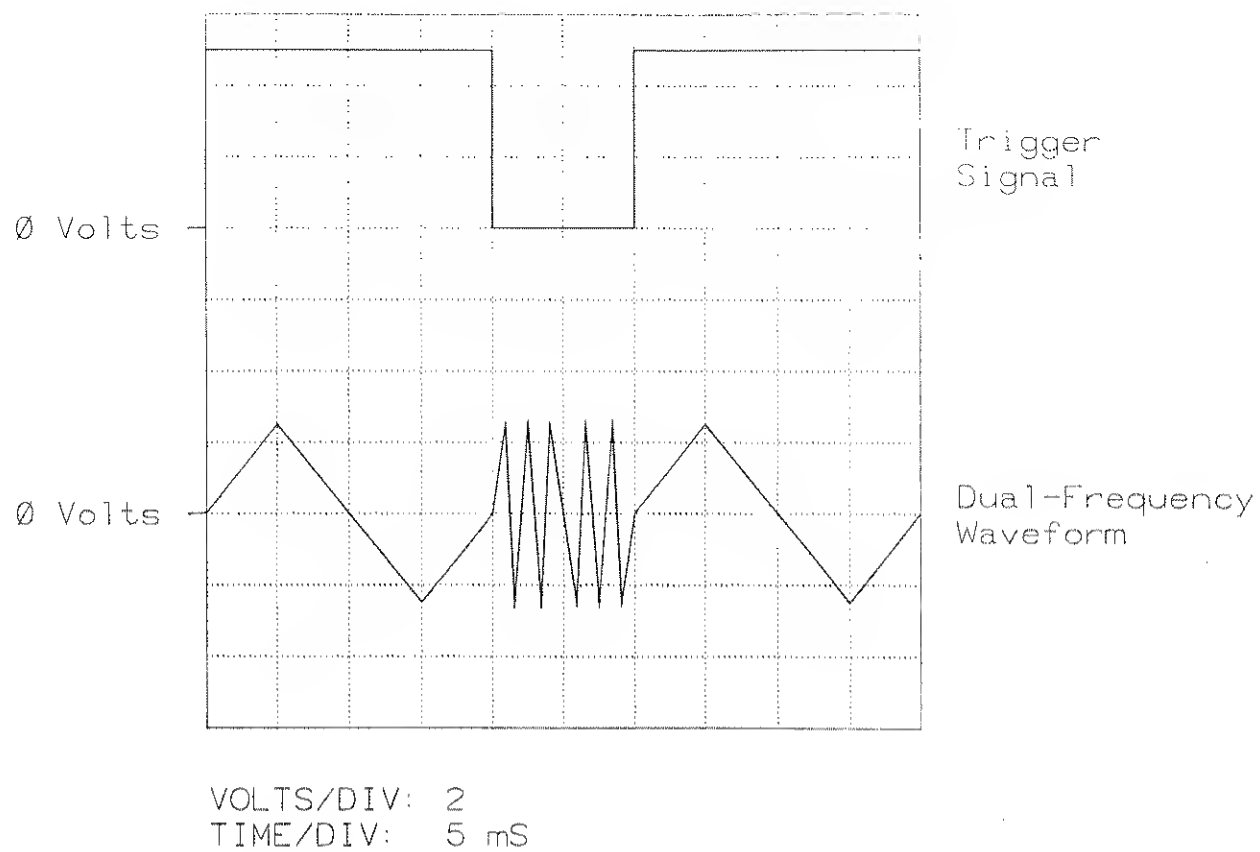
Executing any of the following commands may cause the output waveform to momentarily change to the other of the two frequencies: **ADJUST** commands, **APPLY** commands, **ARANGE ON**, **DCOFF**, **DUTY**, **FREQ**, **IMP**, **RANGE**, and **TRIGMODE**.

The following program enables the module in mainframe slot 200 to output a dual-frequency ramp waveform with an amplitude of 5 VPP. The output frequency is 50 Hz when an externally-generated signal on the TRIGGER connector is high (+5V) and 500 Hz when the signal is low (0V). The resulting output is shown in Figure 12.

```

10 OUTPUT 709; "RST 200;USE 200"
20 OUTPUT 709; "TRIGMODE DUALFR"
30 OUTPUT 709; "FREQ 50,500"
40 OUTPUT 709; "TRIGIN EXT"
50 OUTPUT 709; "APPLY RPV 5"
60 END

```



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Figure 12. Dual-Frequency Waveform Example Output

Command Summary

This section summarizes the commands discussed previously in this manual. For a tutorial on each of these commands, refer to "Using the HP 34521" in this manual. For detailed reference information on each command, refer to the HP 3235 Language Reference Manual.

The commands **ALLOW**, **CRESET**, **CTYPE** or **CTYPE?**, **DTEST**, **FTEST**, **ID?**, **MON**, **PROHIBIT**, **PROHIBIT?**, **RESET**, and **TEST** also apply to the HP 34521 but are not summarized here. These commands are discussed in the HP 3235 Programming and System Information Manual because they are common to many modules.

Commands By Function

<u>Slot Designation</u>	<u>Reference Frequency</u>	<u>Queries</u>
USE	REFIN	ARANGE?
USE?	RIEFIN?	DCRES?
	REFOUT	DELAY?
<u>Signal Output</u>	REFOUT?	OUTPUT?
		RANGE?
APPLY ACV	<u>Output Related</u>	REFIN?
APPLY DCI		RIEOUT?
APPLY DCMEMI	ARANGE	SYNCOUT?
APPLY DCMEMV	ARANGE?	TERM?
APPLY DCV	DCOFF	TRIGIN?
APPLY RPV	DCRES	TRIGOUT?
APPLY SQV	DCRES?	USE?
APPLY WfV	DELAY	
OUTPUT?	DELAY?	
	DUTY	
<u>Remote-Sensing</u>	FREQ	
	IMP	
ADJUST ACV	PANG	
ADJUST DCV	RANGE	
OUTPUT?	RANGE?	
	TERM	
<u>Triggering</u>	TERM?	
SYNCOUT	<u>Precomputing Waveforms</u>	
SYNCOUT?		
TRIGIN	FILLAC	
TRIGIN?	FILLRP	
TRIGMODE	FILLWF	
TRIGOUT		
TRIGOUT?		

Alphabetical Listing

ADJUST ACV	Generates a remote-sensed sinewave voltage. Syntax: <i>ADJUST ACV volts, dmm_slot# [, LIM upper, lower] [, tolerance [, count]]</i>
ADJUST DCV	Generates a remote-sensed DC voltage. Syntax: <i>ADJUST DCV volts, dmm_slot# [, LIM upper, lower] [, tolerance [, count]]</i>
APPLY ACV	Generates an AC sine waveform. Syntax: <i>APPLY ACV pp_amplitude</i>
APPLY DCI	Generates a DC current. Syntax: <i>APPLY DCI amps</i>
APPLY DCMEMI	Generates a triggered sequence of low-resolution DC current values. Syntax: <i>APPLY DCMEMI length, array_name</i>
APPLY DCMEMV	Generates a triggered sequence of low-resolution DC voltage values. Syntax: <i>APPLY DCMEMV length, array_name</i>
APPLY DCV	Generates a DC voltage. Syntax: <i>APPLY DCV volts</i>
APPLY RPV	Generates an AC ramp waveform. Syntax: <i>APPLY RPV pp_amplitude</i>
APPLY SQV	Generates an AC square waveform. Syntax: <i>APPLY SQV pp_amplitude</i>
APPLY WFV	Generates an AC arbitrary waveform. Syntax: <i>APPLY WFV pp_amplitude [, array_name]</i>
ARANGE	Enables or disables the autorange function. Syntax: <i>ARANGE [control]</i>

ARANGE?	Returns "ON" or "OFF" indicating whether the autorange function is enabled or disabled. Syntax: ARANGE?
DCOFF	Specifies the DC offset voltage for sine, ramp, square, or arbitrary waveforms. Syntax: DCOFF <i>volts</i>
DCRES	Selects the high- or low-resolution mode for DC voltage and current outputs. Syntax: DCRES <i>mode</i>
DCRES?	Returns "HIGH" or "LOW" indicating whether the high- or low-resolution mode is selected. Syntax: DCRES?
DELAY	Specifies a time interval during which outputs from the module are allowed to settle before the next command is executed. Syntax: DELAY [<i>time</i>]
DELAY?	Returns the programmed delay time in seconds. If no DELAY command has been executed, DELAY? returns the default delay time. Syntax: DELAY?
DUTY	Specifies the duty cycle between 5% and 95% for ramp and square waveforms. Syntax: DUTY <i>%_duty</i>
FILLAC	Precomputes sine waveforms to enhance output speed. Syntax: FILLAC <i>integer_array</i>
FILLRP	Precomputes ramp waveforms to enhance output speed. Syntax: FILLRP <i>integer_array</i> [, <i>%_duty</i>]
FILLWF	Precomputes arbitrary waveforms to enhance output speed. Syntax: FILLWF <i>real_array</i> , <i>integer_array</i>
FREQ	Specifies the output frequency for sine, ramp, square, and arbitrary waveforms. In the dual-frequency mode, the <i>freq_1</i> parameter corresponds to a HIGH level. Syntax: FREQ <i>freq_1</i> [, <i>freq_2</i>]

IMP	Selects the 0Ω or 50Ω output impedance mode for DC voltage and AC voltage waveform outputs. Syntax: <i>IMP mode</i>
OUTPUT?	Returns the last programmed output level (voltage or current) from the module. Syntax: OUTPUT?
PANG	Specifies the phase angle for AC waveforms. Syntax: <i>PANG degrees</i>
RANGE	Selects the output range or enables the autorange function. Syntax: <i>RANGE [max_output]</i>
RANGE?	Returns the present output range. Syntax: RANGE?
REFIN	Selects the reference frequency input source for slave modules in the AC synchronized mode. Syntax: <i>REFIN source</i>
REFIN?	Returns a string indicating which reference frequency input source is selected. Syntax: REFIN?
REFOUT	Selects the reference frequency output destination for the master module in the AC synchronized mode. Syntax: <i>REFOUT destination</i>
REFOUT?	Returns a string indicating which reference frequency output destination is selected. Syntax: REFOUT?
SYNCOUT	Controls the destination of the SYNC signal for AC waveform outputs. Syntax: <i>SYNCOUT destination</i>
SYNCOUT?	Returns "OFF", "TB0", or "TB1" indicating which SYNC destination has been selected. Syntax: SYNCOUT?

TERM	Selects the front OUTPUT connector or one of the HP 3235's analog buses as the destination for outputs from the module. Syntax: TERM [<i>mode</i>]
TERM?	Returns a string indicating which output terminal has been selected. Syntax: TERM?
TRIGIN	Selects the module's trigger event. Syntax: TRIGIN <i>event</i>
TRIGIN?	Returns a string indicating which trigger event has been selected. Syntax: TRIGIN?
TRIGMODE	Selects one of three available AC triggering modes. Syntax: TRIGMODE <i>mode</i>
TRIGOUT	Enables or disables outputs from the module's TRIGGER connector. Syntax: TRIGOUT <i>control</i>
TRIGOUT?	Returns a string indicating whether outputs from the module's TRIGGER connector are enabled or disabled. Syntax: TRIGOUT?
USE	Designates the HP 3235 slot to receive subsequent multimeter module, source module, digital I/O module, or D/A converter module commands. Syntax: USE <i>device#</i>
USE?	Returns the presently designated USE slot. Syntax: USE?

Specifications

The following specifications describe the module's warranted performance over the temperature range 0°C to 55°C. Information marked by the (*Typical*) designation is helpful in applying the module but is non-warranted information.

DC Voltage

DC Volts Output Characteristics

Output Ranges:

High Resolution Mode (0Ω): 1V, 10V
High Resolution Mode (50Ω): .5V, 5V
Low Resolution Mode (0Ω): .15625V, .3125V, .625V, 1.25V, 2.5V, 5V, 10V
Low Resolution Mode (50Ω): .078125V, .15625V, .3125V, .625V, 1.25V, 2.5V, 5V

Maximum Programmed Output:

High Resolution Mode (0Ω): 1.25V on 1 volt range 10.25V on 10 volt range
High Resolution Mode (50Ω): .625V on .5 volt range, 5.125V on 5.0 volt range
Low Resolution Mode: maximum programmed output equal to output range

Output Resistance:

zero ohm mode: < .5 Ω
50 Ω mode: 49.9 Ω to 50.6 Ω

Resolution:

High Resolution Mode:	Range	0Ω Mode Resolution	50Ω Mode Resolution
	1V	1 μV	.5 μV
	10V	10 μV	5 μV

Low Resolution Mode:	Range	0Ω Mode Resolution	50Ω Mode Resolution
	.078125V	—	40μV
	.15625V	79 μV	79 μV
	.3125V	157 μV	157 μV
	.625V	313 μV	313 μV
	1.25V	625 μV	625 μV
	2.5V	1250 μV	1250 μV
	5V	2.5 mV	2.5 mV
	10V	5.0 mV	—

Noise & spurious responses (to 250KHz):

	Peak-to-Peak	RMS
High Resolution Mode	2mV	.6mV
Low Resolution Mode	.2% of range + 2mV	.02% of range + 60μV

Current compliance: 100mA on all ranges

Settling time (Delay 0):

High Resolution Mode:
.1% of step: 20 mSEC
.001% of step: 40 mSEC
(1 SEC if function changed)
Low Resolution Mode:
.1% of step (0Ω Mode): 100 μSEC
(50Ω Mode): 25 μSEC
.5% of step (50Ω Mode): 5 μSEC

Overshoot:

High Resolution Mode: <5% of step + .15% of range
Low Resolution Mode: <30% of step + 2% of range

DC Volts Accuracy (< 10 Hz noise): \pm (% of programmed output + volts), Ω impedance mode, > 1Mohm load. Tcal is the temperature of calibration from 18°C to 28°C. One hour warm-up.

24 HOUR: Tcal \pm 1°C. Accuracy relative to calibration standard.

High Resolution Mode		Low Resolution Mode	
Range	Accuracy	Range	Accuracy
10V	.00071% + 85 μ V	10V	.087% + 20mV
1V	.00077% + 15 μ V	5V	.087% + 9.7mV
		2.5V	.087% + 4.9mV
		1.25V	.087% + 2.5mV
		.625V	.087% + 1.3mV
		.3125V	.087% + .67mV
		.15625V	.087% + .37mV

90 DAY: Tcal \pm 5°C.

High Resolution Mode		Low Resolution Mode	
Range	Accuracy	Range	Accuracy
10V	.0047% + 260 μ V	10V	.20% + 44mV
1V	.0052% + 36 μ V	5V	.20% + 22mV
		2.5V	.20% + 11mV
		1.25V	.20% + 5.6mV
		.625V	.20% + 2.9mV
		.3125V	.20% + 1.6mV
		.15625V	.20% + .89mV

1 YEAR: Tcal \pm 5°C.

High Resolution Mode		Low Resolution Mode	
Range	Accuracy	Range	Accuracy
10V	.0063% + 290 μ V	10V	.232% + 51mV
1V	.0069% + 43 μ V	5V	.232% + 26mV
		2.5V	.232% + 13mV
		1.25V	.232% + 6.5mV
		.625V	.232% + 3.3mV
		.3125V	.232% + 1.8mV
		.15625V	.232% + 1.1mV

Temperature Coefficient:

\pm (% of programmed output + volts)/°C

High Resolution Mode		Low Resolution Mode	
Range	Accuracy	Range	Accuracy
10V	.00031% + 12 μ V	10V	.011% + 2400 μ V
1V	.00037% + 1.8 μ V	5V	.011% + 1200 μ V
		2.5V	.011% + 600 μ V
		1.25V	.011% + 300 μ V
		.625V	.011% + 160 μ V
		.3125V	.011% + 82 μ V
		.15625V	.011% + 50 μ V

Multiply the temp. coef. by the difference between the operating temperature and Tcal to determine the additional error for operation outside temperature ranges specified above.

DC Current

DC Current Output Characteristics

Output Ranges (for both High and Low Resolution):
.1mA, 1mA, 10mA, 100mA

Maximum Programmed Output is equal to the output range value on all ranges

Output Resistance:

Range	High Resolution	Low Resolution
100mA	> 3.1Mohm	> .32 Mohm
10mA	> 210Mohm	> 41 Mohm
1mA	> 2500Mohm	> 480 Mohm
.1mA	> 10000Mohm	> 4800 Mohm

Resolution:

Range	High Resolution	Low Resolution
.1mA	.1nA	50nA
1mA	1nA	500nA
10mA	10nA	5 μ A
100mA	100nA	50 μ A

Noise & spurious responses (to 250KHz):

	peak-to-peak	rms
High Resolution Mode	.02% of range + .7 μ A	.003% of range + 70nA
Low Resolution Mode	.04% of range + .7 μ A	.01% of range + 70nA

Voltage compliance:

\pm 8.0 Volts on 100mA range
 \pm 10.0 Volts on all other ranges

Max Resistive Load for specified accuracy = voltage compliance/range in amps

Settling time (Delay 0):

High Resolution Mode:

.1% of step: 20 mSEC
.001% of step: 40 mSEC
.003% of step on 10 mA range: 40 mSEC
.01% of step on 100 mA range: 40 mSEC
(1 SEC if function changed)

Low Resolution Mode:

.1% of step: 100 μ SEC
(30 mSEC if range changed)

Overshoot:

High Resolution Mode: <5% of step + .15% of range
Low Resolution Mode: <30% of step + 2% of range

DC Current Accuracy (< 10Hz noise): \pm (% of programmed output + amps), < Rout/10⁶ ohm load, Tcal is the temperature of calibration from 18°C to 28°C.

24 HOUR: Tcal \pm 1°C. After one hour warm-up. Accuracy relative to calibration standard.

High Resolution Mode		Low Resolution Mode	
Range	Accuracy	Range	Accuracy
100mA	.0120% + 2.1 μ A	100mA	.16% + 200 μ A
10mA	.0031% + 98nA	10mA	.16% + 30 μ A
1mA	.0010% + 9.5nA	1mA	.15% + 1.90 μ A
.1mA	.0009% + 1.9nA	.1mA	.15% + .190 μ A

90 DAY: Tcal \pm 5C. After one hour warm-up.

High Resolution Mode		Low Resolution Mode	
Range	Accuracy	Range	Accuracy
100mA	.0220% + 3.8 μ A	100mA	.35% + 470 μ A
10mA	.0110% + 860nA	10mA	.35% + 60 μ A
1mA	.0080% + 85nA	1mA	.28% + 4.5 μ A
.1mA	.0080% + 9.5nA	.1mA	.28% + .45 μ A

1 YEAR: Tcal \pm 5°C. After one hour warm-up.

High Resolution Mode		Low Resolution Mode	
Range	Accuracy	Range	Accuracy
100mA	.0260% + 4.4 μ A	100mA	.39% + 550 μ A
10mA	.0130% + 910nA	10mA	.39% + 69 μ A
1mA	.0100% + 90nA	1mA	.32% + 5.3 μ A
.1mA	.0100% + 10nA	.1mA	.32% + .53 μ A

Temperature Coefficient: \pm (% of programmed output + amps)/°C

High Resolution Mode		Low Resolution Mode	
Range	Accuracy	Range	Accuracy
100mA	.00070% + 150nA	100mA	.011% + 25 μ A
10mA	.00036% + 14nA	10mA	.019% + 2.8 μ A
1mA	.00036% + 1.2nA	1mA	.011% + 240nA
.1mA	.00036% + .16nA	.1mA	.011% + 24nA

Multiply the temp. coef. by the difference between the operating temperature and Tcal to determine the additional error for operation outside temperature range specified above.

AC Voltage

AC Volts Output Characteristics (sine, square, ramp, arbitrary)

Frequency Range: 0 to 1 MHz for sine, arbitrary and square (at 50% duty cycle)
0 to 100 kHz for ramp
0 to 100 kHz for square w/Duty cycle not equal to 50%

Peak-to-Peak Output Ranges (into 50 Ω load):

50 Ω mode: .15625V, .3125V, .625V, 1.25V, 2.5V, 5V, 10V
0 Ω mode: .3125V, .625V, 1.25V, 2.5V, 5V, 10V, 20V

Maximum Programmed Peak-to-Peak Output is equal to the output range on all ranges

Output Resistance:

0 Ω mode: < .5 Ω
50 Ω mode: 50.6 Ω to 49.9 Ω

Current compliance: 100mA on all ranges

Amplitude and/or Offset Resolution:

Range (Peak-Peak)	50 Ω Mode Resolution	0 Ω Mode Resolution
.15625V	79 μ V	—
.3125V	157 μ V	157 μ V
.625V	313 μ V	313 μ V
1.25V	625 μ V	625 μ V
2.5V	1250 μ V	1250 μ V
5V	2.5 mV	2.5 mV
10V	5.0 mV	5.0 mV
20V	—	10.0 mV

Amplitude can be set from 10% to 100% of range.

DC offset can be set such that the peak AC value plus the magnitude of the DC offset does not exceed range/2.

Arbitrary waveforms are defined over the unitless range from -1 to 1 with 1/2040 resolution.

Sine, Ramp (< 10 kHz), and Arbitrary Waveform aberrations (50 Ω Mode): < 1% of p-p measured with amplitude > 50% of range

Ramp Linearity to 1kHz (50 Ω Mode):

.3% of p-p value measured @ 50% duty cycle from 10% to 90% point

Ramp duty cycle range: 5% to 95% with <.1% resolution

Sinewave Characteristics (50 Ω Mode):

Frequency	Harmonic and Spurious Levels (ampl \geq 50% of range)*	THD (ampl \geq 50% of range)	Flatness, in reference to 1 kHz
<3 kHz	< - 62 dB	< - 56 dB	.07 dB
to 10 kHz	< - 62 dB	< - 50 dB	.07 dB
to 30 kHz	< - 55 dB	< - 48 dB	.07 dB
to 100 kHz	< - 46 dB	< - 46 dB	.20 dB
to 300 kHz	< - 40 dB	—	.60 dB
to 1 MHz	< - 40 dB	—	2.00 dB

* additional fixed spurious response >4MHz: 500 μ Vrms

Squarewave Characteristics (50 Ω Mode):

risetime: <250 nSEC, 10% to 90%
settling time: <1 μ SEC to 1% of amplitude
overshoot: < 5% of peak to peak amplitude
duty cycle range: 5% to 95%, 0 to 100 kHz
50% above 100 kHz
duty cycle accuracy: \pm (0.8% of period + 80 nSEC)

Frequency Resolution: .001 Hz

Frequency Accuracy: \pm 50 ppm, 18 to 28°C

Frequency Temperature Coefficient: \pm 1ppm/°C

Phase Offset:

Range: -360 to +360 degrees
Resolution: < .001 degree

AC Volts Amplitude or Offset Accuracy:¹

sine, square, ramp, arbitrary: \pm (% of programmed output + % of range) @ 1kHz, 50 Ω mode into >1M Ω , <200 pF with amplitude programmed to \geq 50% of range. The output is specified into >1M Ω in order to eliminate the effects of the 50 Ω output resistance error on accuracy. Tcal is the temperature of calibration from 18°C to 28°C. One hour warm-up.

24 HOUR: Tcal \pm 1°C. Accuracy relative to calibration standard. (all ranges)²

Sine, Ramp, Arbitrary Waveforms	Square Waveforms
.16% output + .25% range	.084% output + .42% range

90 DAY: Tcal \pm 5°C. (all ranges)²

Sine, Ramp, Arbitrary Waveforms	Square Waveforms
.35% output + .41% range	.39 output + .56% range

1 YEAR: Tcal \pm 5°C. (all ranges)²

Sine, Ramp, Arbitrary Waveforms	Square Waveforms
.40% output + .42% range	.49% output + .60 range

Temperature Coefficient:

\pm (% of programmed output + % of range)/°C

Range ²	Sine, Arbitrary, Ramp Waveforms	Square Waveforms
.15625V	.0180% + 25 μ V	.034% + 24 μ V
.3125V	.0180% + 50 μ V	.034% + 47 μ V
.625V	.0180% + 100 μ V	.034% + 94 μ V
1.25 V	.0180% + 200 μ V	.034% + 188 μ V
2.5 V	.0180% + 400 μ V	.034% + 375 μ V
5.0 V	.0180% + 800 μ V	.034% + 750 μ V
10.0 V	.0180% + 1.6 mV	.034% + 1.5 μ V

Multiply the temp. coef. by the difference between the operating temperature and Tcal to determine the additional error for operation outside temperature ranges specified above.

¹ The accuracy specifications must be applied once to amplitude and again to offset.

² Ranges are peak-to-peak value of amplitude for 50 Ω Mode into 50 Ω load.

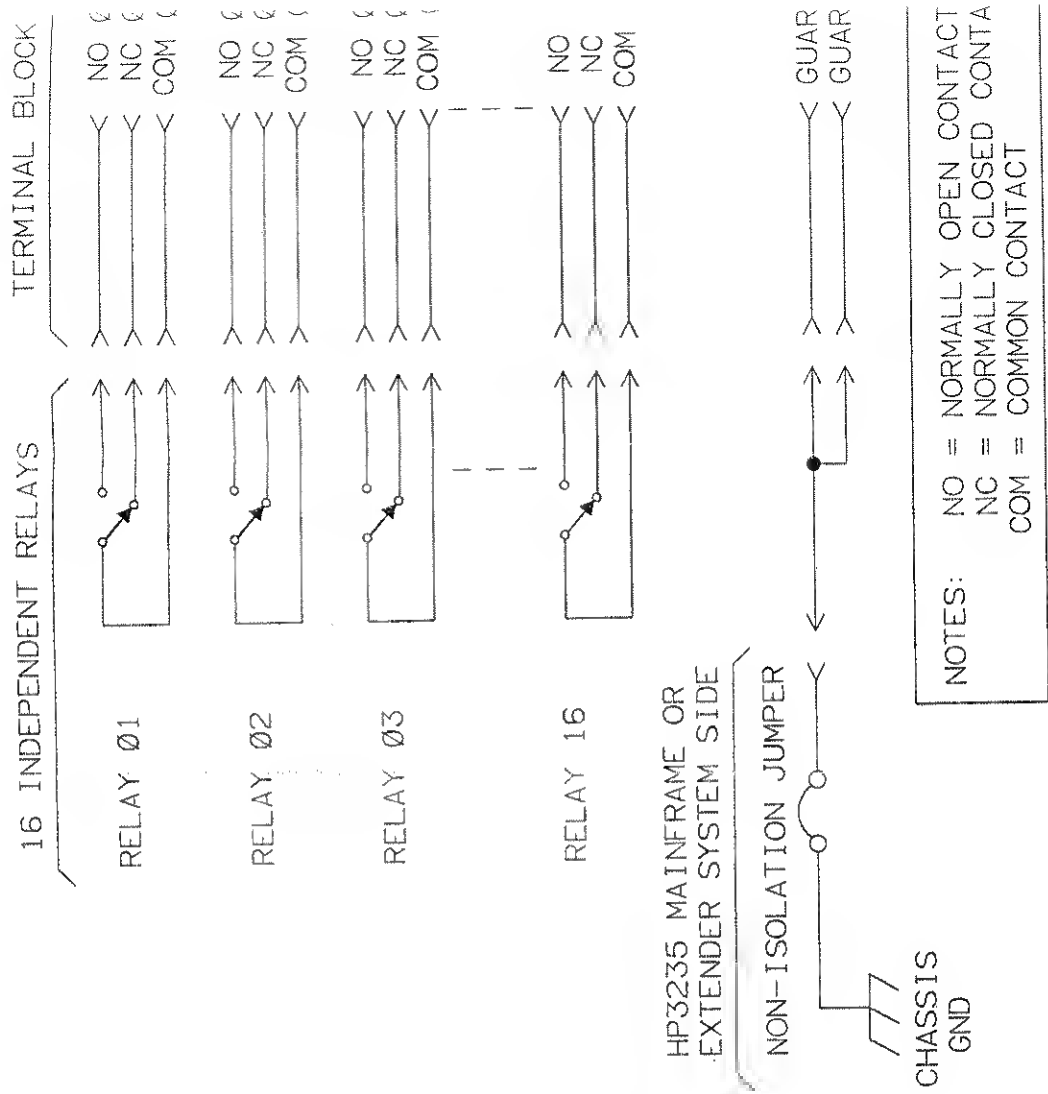
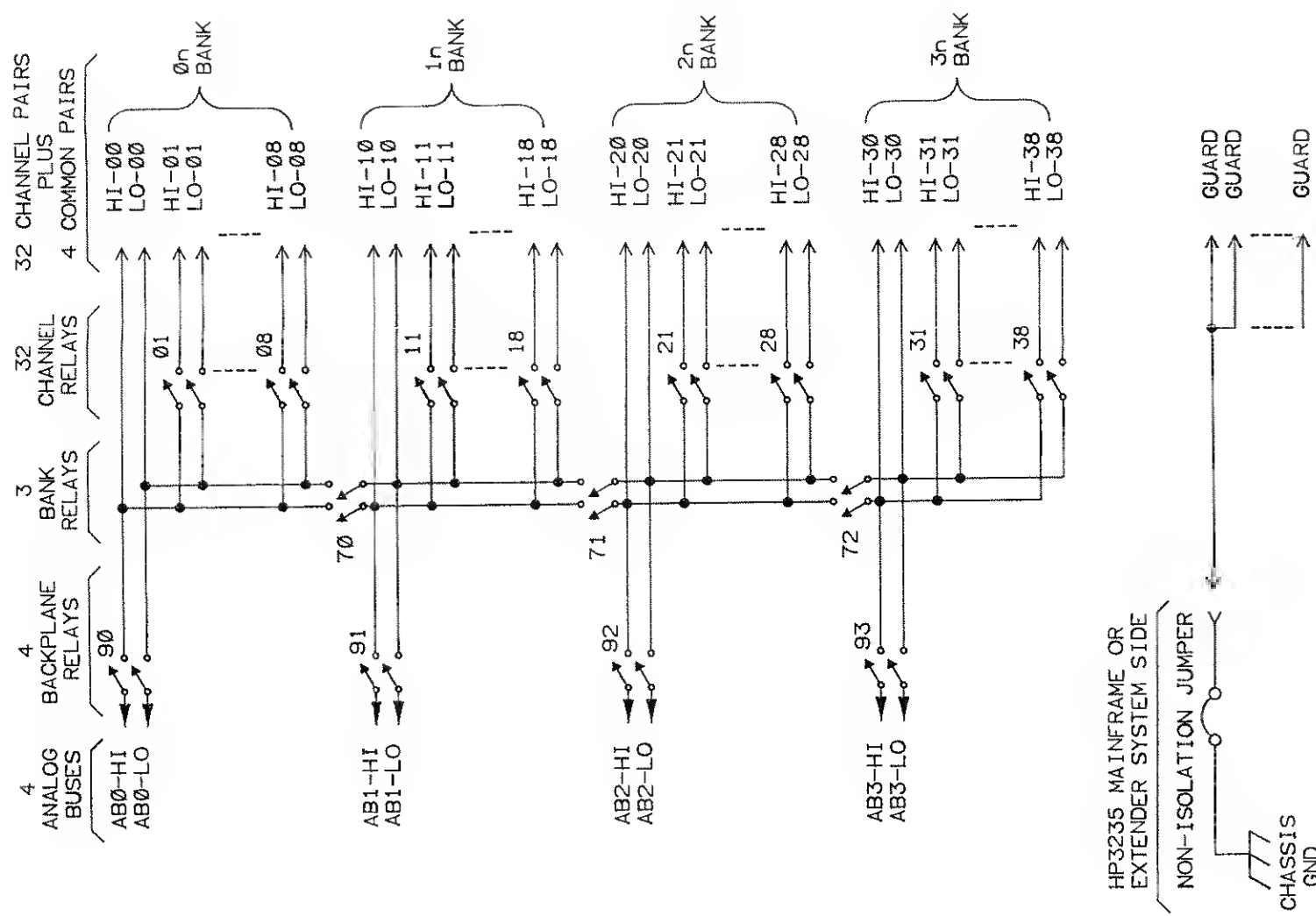
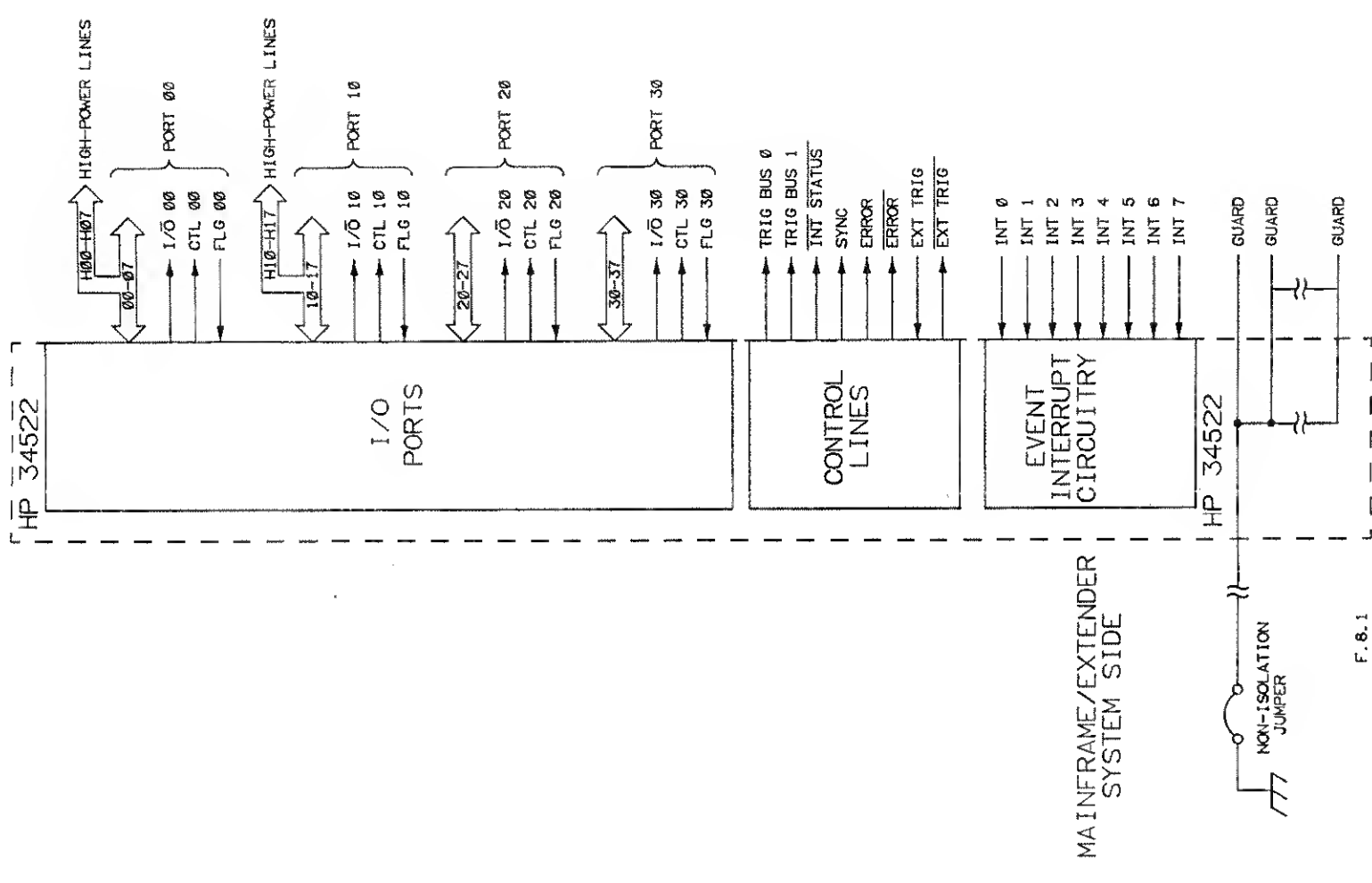
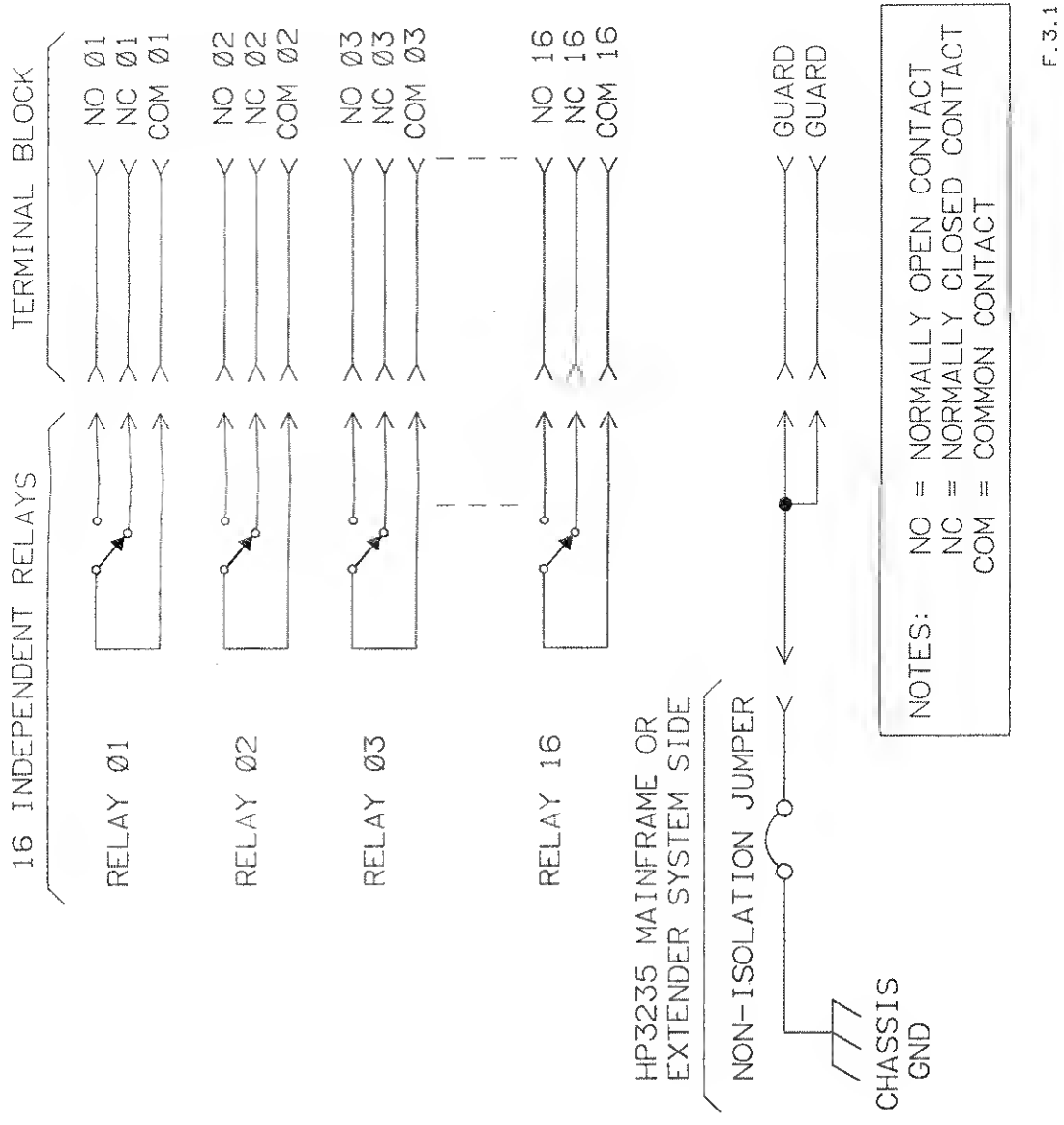
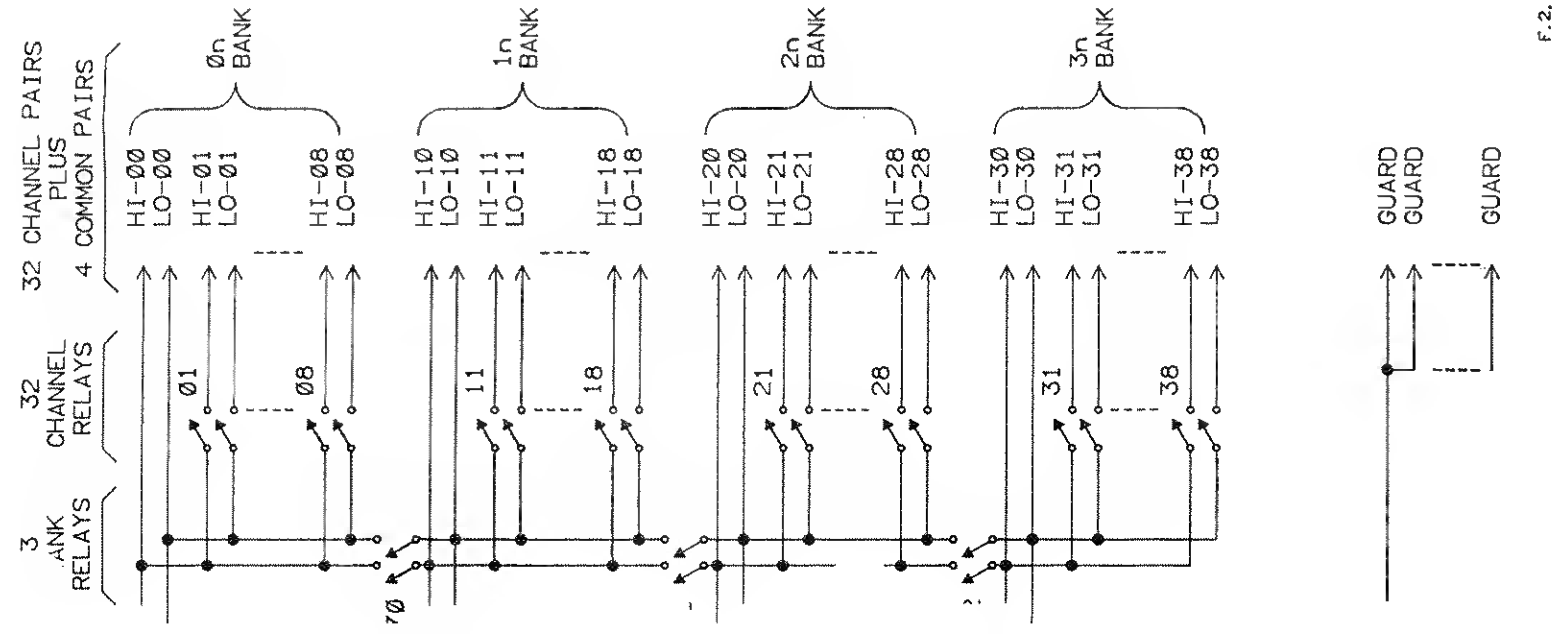


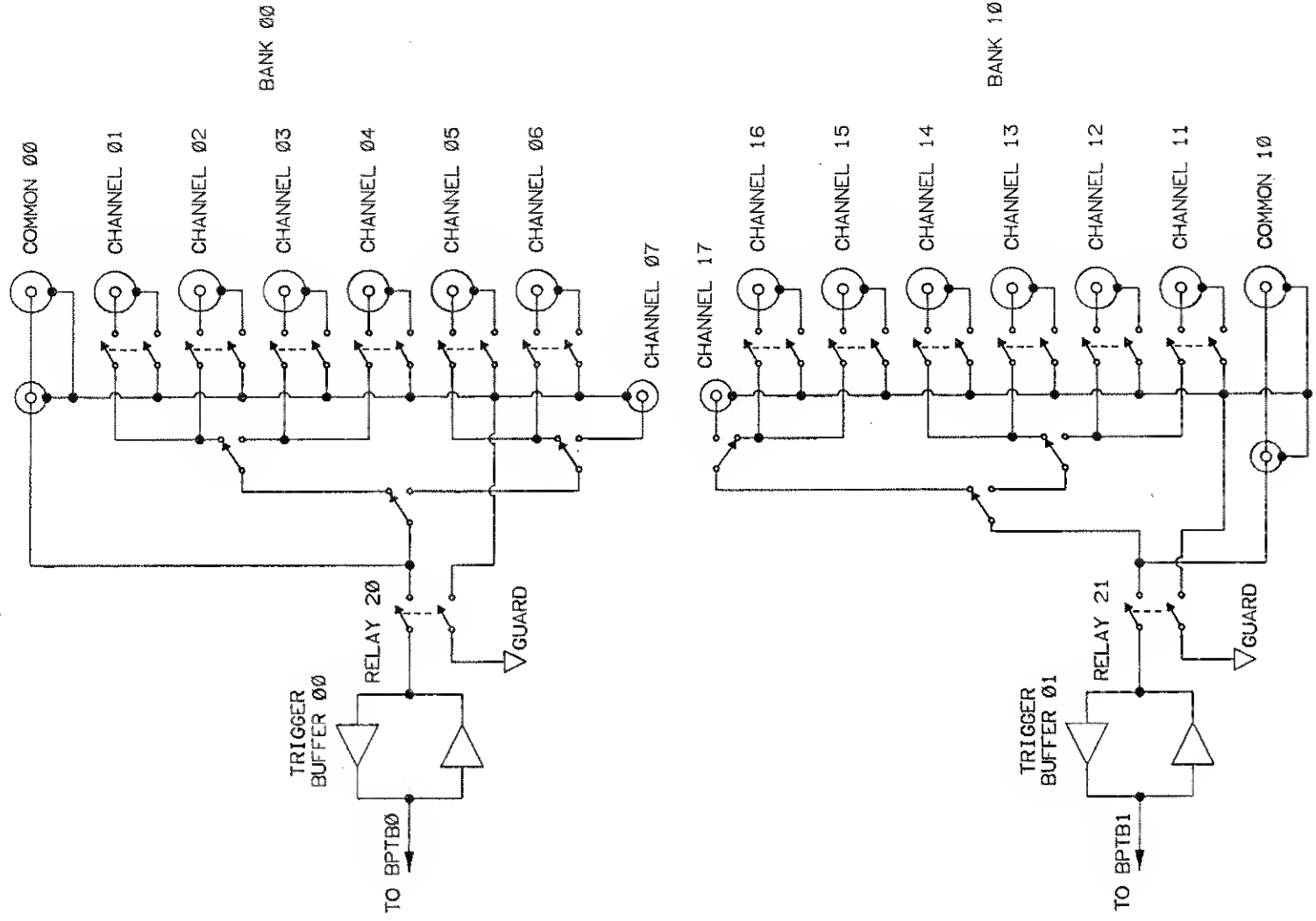
Figure Appendix A-2
HP 34503 General Purpose Relay Module



F.2.1

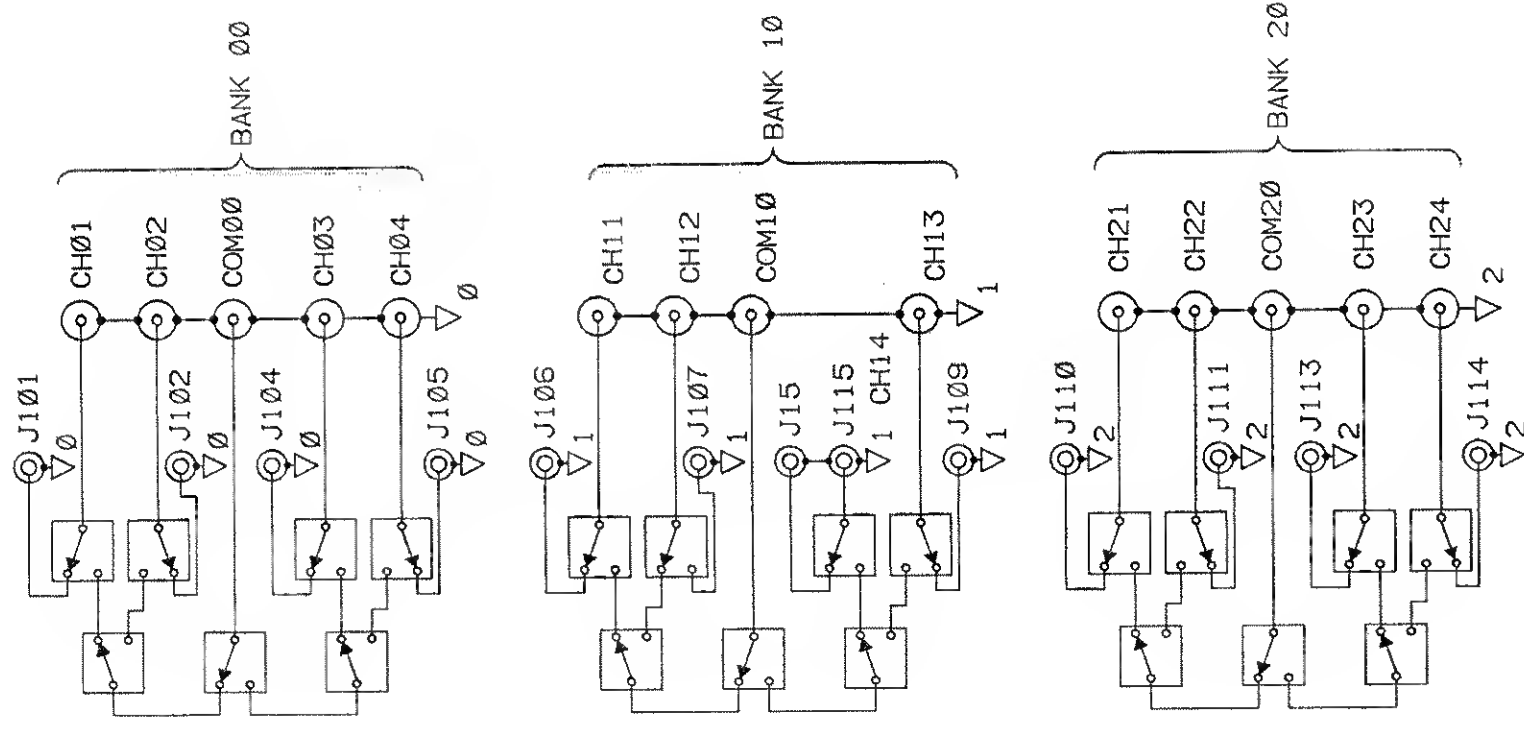
Figure Appendix A-1
HP 34501/2/7 32-Channel Relay Multiplexer Modules





F.4.1

Figure Appendix A-4
HP 34504 Coaxial Multiplexer Module

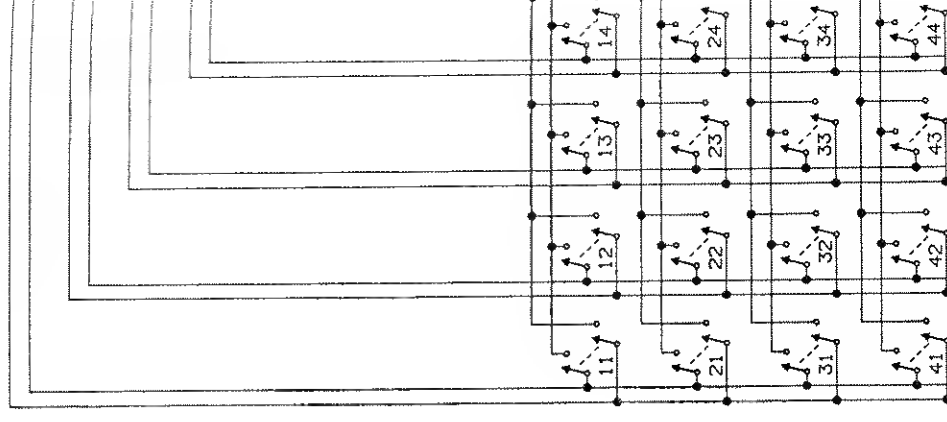


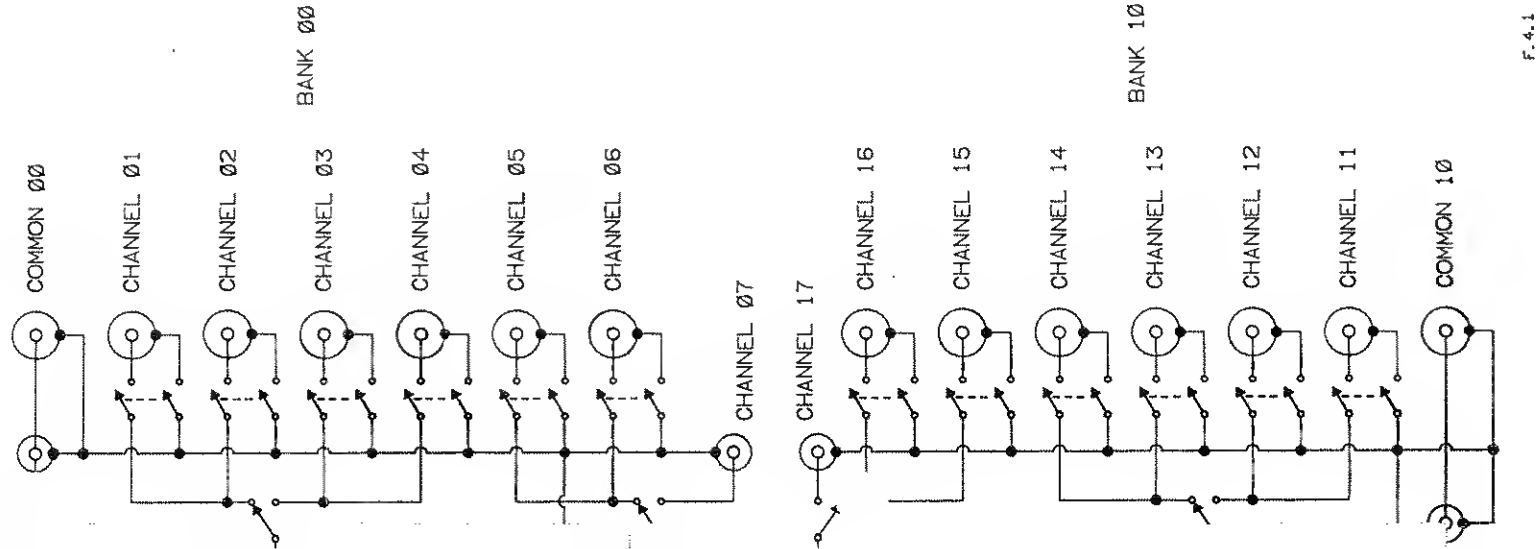
F.5.1

Figure Appendix A-5
HP 34505 RF Multiplexer Module

BNC CONNECTOR

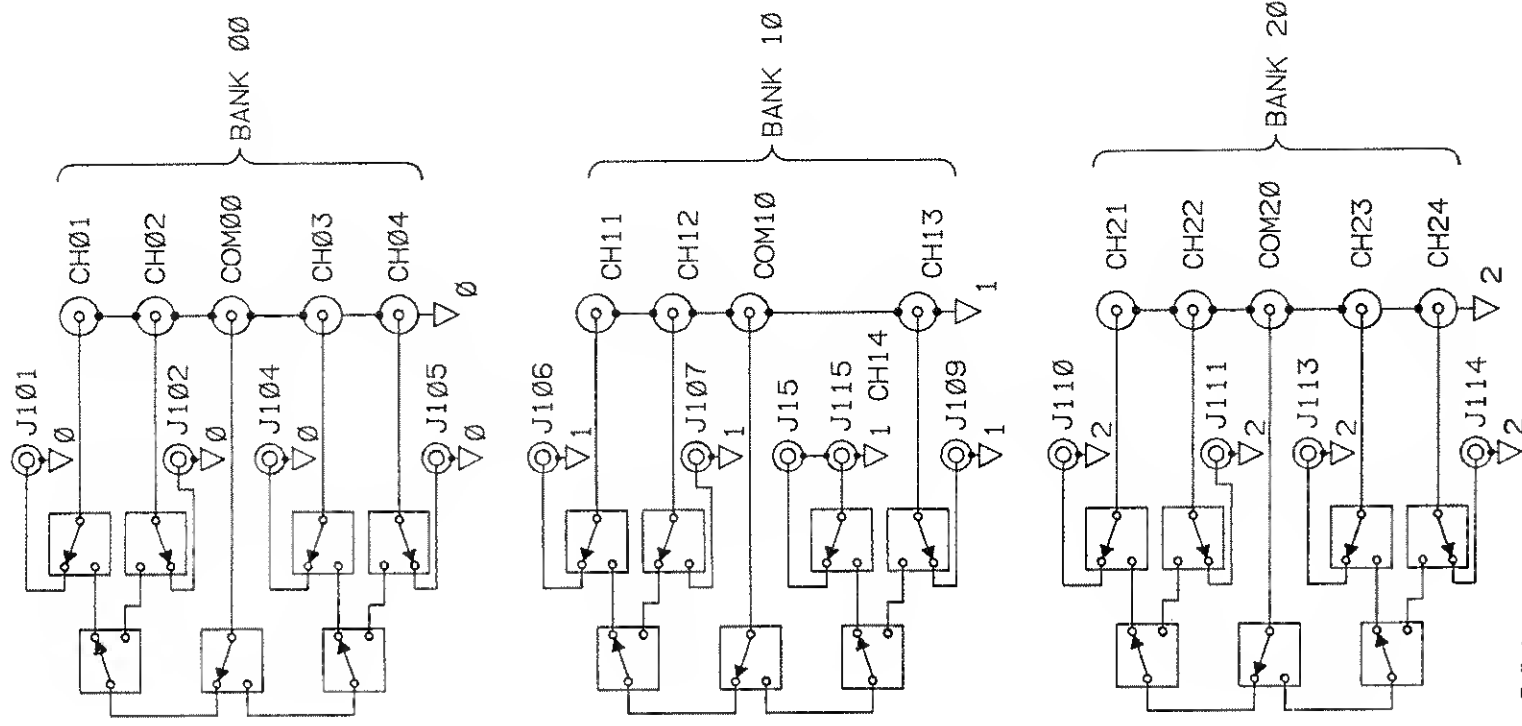
SMB CONNECTOR





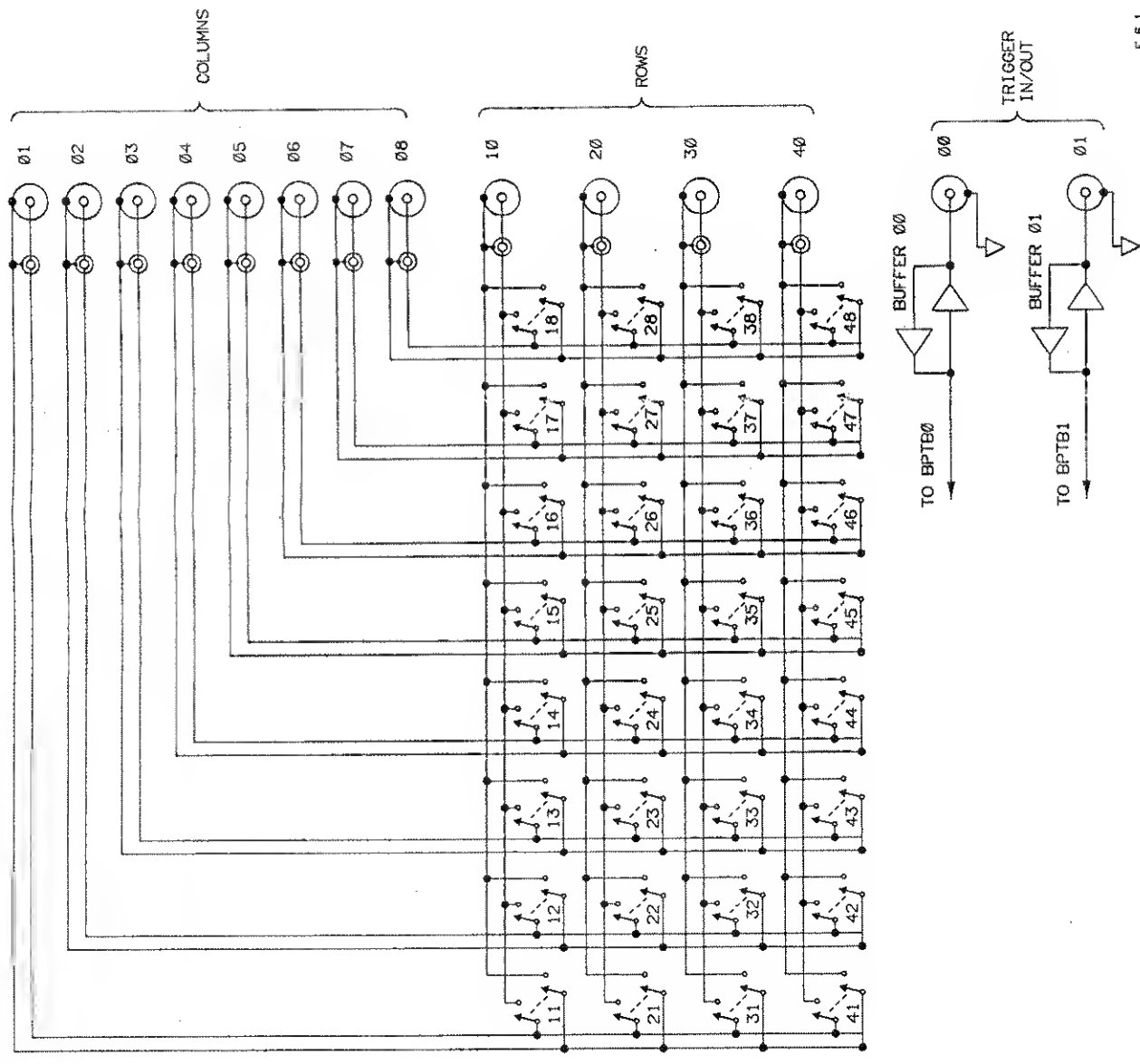
F.4.1

Appendix A-4
Multiplexer Module



F.5.1

Figure Appendix A-5
HP 34505 RF Multiplexer Module



F.6.1

BNC CONNECTOR

SMB CONNECTOR

Figure Appendix A-6
HP 34506 Coaxial Matrix Module

